COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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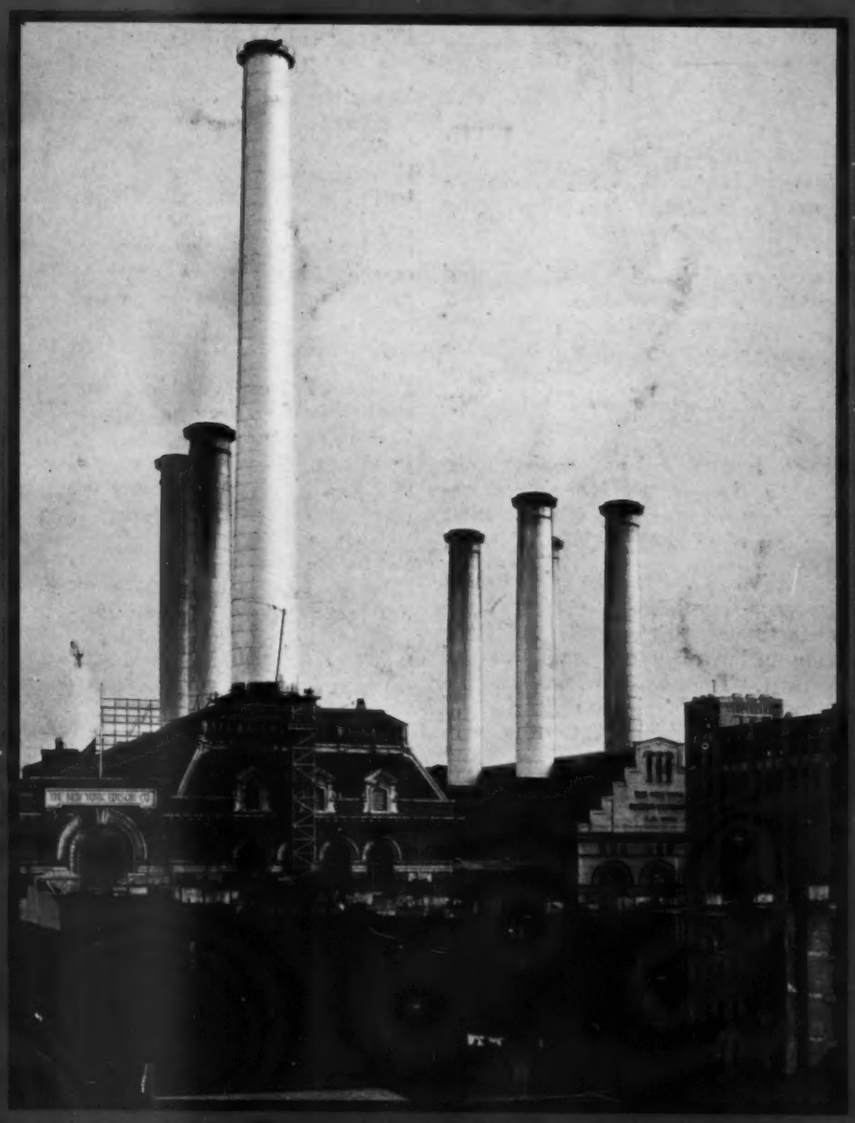

The new stack on the Waterside Station, New York, which will handle the gases from the large high-pressure boilers, extends approximately 450 ft above the street

Factors in the Design of Superposed Turbines

Equipment and Operating Data on the Federal Central Heating Plant

Availability of MODERN BOILER UNITS

NUMBER SIX of a series of advertisements in which subjects of current interest to utility engineers and consultants are briefly reviewed and present trends indicated. Subjects covered are as follows: (*1*) *Superposition;* (*2*) *Furnace Design;* (*3*) *Heat Recovery;* (*4*) *Heat Cycles;* (*5*) *Boilers for High Pressures and Temperatures;* (*6*) *Availability of Modern Boiler Units.*

THE following statement is quoted from a paper, "The Performance of Modern Steam Generating Units" by C. F. Hirshfeld and G. U. Moran, Detroit Edison Company, presented at the annual meeting of the A.S.M.E. in 1929:

"It is the hope of every central-station designer and operator that some day the steam-generating equipment may be brought to such a stage of perfection of design and construction that, when properly operated, it will have the same degree of availability for service as characterizes the modern steam turbine, attached generator and subsidiary or auxiliary equipment."

The fact that this hope has now been achieved in practice is a real tribute to the progressiveness and resourcefulness of designers of steam-generating equipment and to the helpful cooperation of central station engineers.

Not only are recent availability records of modern steam-generating units comparable with those of turbine-generators but in several instances installations have been made on the definite assumption of equal availability of boiler and turbine equipment. Two installations in this category are the 80,000-kw Port Washington Station of The Milwaukee Electric Railway & Light Company and the 18,750-kw Provo Station of the Utah Power and Light Company. Each of these stations relies on a single steam-generating unit.

The term "availability" was defined in the paper referred to above as the ratio between the sum of hours during which the unit was steaming, banked or available for service, to the total number of hours reported. For 244 boilers covered in the final installment of this paper, presented in December 1932, the total hours reported represented periods of from one to three years. The availability for a group of 122 stoker-fired boilers was 83.1 per cent. For 82 pulverized-fuel-fired boilers it was 86.9 per cent. Relatively few steam-generating units have been installed since these data were obtained, but such figures as have been published in connection with comparatively recent installations show substantially better performance. Data for some of these installations is as follows: availability of one boiler unit for a two-year period—94.5 per cent; one boiler for one year—91.2 per cent; two boilers for sixteen months—90 per cent; three boilers for one year—98.1 per cent, and the same three boilers for four years—96.3 per cent; one boiler for one year—90.1 per cent. The last mentioned unit is in a heating plant and during the past heating season of seven months its availability was 97 per cent. Throughout this entire period its production averaged 740,000 lb of steam per hr. In this plant a unit is considered available only when it can be placed in service within one hour. The yearly availability of 90.1 per cent could have been increased if desired as inspection and maintenance work, done at convenience during the light-load summer months, was distributed over a longer period than necessary.

It is hardly necessary to emphasize the economic importance of high availability. Equipment is producing a return on investment only when it is in use. When it is idle there is no reduction in fixed charges, and additional losses are incurred if the load must be transferred to less efficient units, as is generally the case. The larger the investment the unit represents, the more important continuity of service becomes. In times of rapidly increasing load, when an extra burden is thrown on a system's more efficient units for the extensive period required to design and install additional capacity, high availability of such units is a tremendous advantage.

One of the principal factors affecting continuity of service is slag accumulation. With coals of low ash fusion temperature, it is essential that the furnace and boiler be designed to prevent excessive slag deposits on heating surfaces. This can be accomplished by a design which provides sufficient heat-absorbing surface in the furnace to reduce temperatures of gases entering the boiler below the softening temperature of the ash. Attainment of this condition requires conservative combustion rates and prevention of flame impingement on boiler tubes. In furnaces of the dry bottom type, a cooling zone in the lower part of the furnace effected by means of a horizontal water screen is essential if slag accumulation in the ash pit is to be avoided.

Other important factors for assuring high availability are adequate water circulation throughout and effective treatment of feedwater.

Improvements of recent years in the design and construction of stokers permit high availability for such equipment under conditions of proper operation, use of suitable coals and reasonable limitation of preheated air temperature. Pulverizers and burners have also been improved and, properly operated, are capable of continuous service for long periods. The use of water-cooled walls with no refractories in the lower part of the furnace has virtually eliminated the necessity of shutdowns for furnace inspection and repairs.

With accurate information on fuel and load conditions, it is now possible to design steam-generating units which, after allowance for the occasional inspections dictated by sensible operation, will be capable of practically 100 per cent availability. Such continuity of service may not be attained the first year when a certain amount of time is required for initial tuning up and adjustments, and subsequent interruptions may attend the development of some peculiar and unforeseeable condition, but, except for such occurrences, it can be substantially achieved.

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME EIGHT NUMBER FIVE

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H. STUART ACHESON, *General Representative*

ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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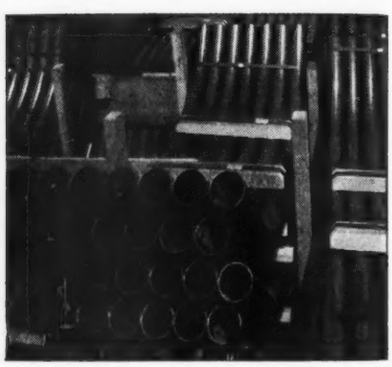
SAFER TUBES AND *a Mind at Rest . . .*



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EDITORIAL

Not Class I Welding

Under title of "Trepanned Plugs from Welded Seams," the October issue of *The Locomotive*, published by The Hartford Steam Boiler Inspection and Insurance Company, reports the findings of that company during the past two years in trepanning and examining plugs from fusion-welded seams of pressure vessels for the purpose of judging the quality of the weld and deciding upon the acceptability of the vessel for insurance.

Although a great many plugs were examined during that period, to quote from the text, "there is yet to be found one which shows a perfectly sound weld." Photographs of a number of specimens are reproduced and reveal well-defined defects of several kinds, such as no fusion of weld metal in the lower part of the welding groove, poor fit-up of plates, slag on the fusion line, porosity, etc.

Nowhere in the article is reference made to the class of welding involved. Therefore, in view of the apparently serious indictment of fusion welding, the Editor of COMBUSTION communicated with the Hartford Company and received a reply confirming his surmise that the article referred to what is known as Class II welding; that power boilers were not involved, nor Class I welding that had been X-rayed and stress-relieved.

In this connection it is in order to quote a statement by E. R. Fish, Chief Engineer of the Boiler Division, The Hartford Steam Boiler Inspection and Insurance Company, in a paper at the recent World Power Conference Round Table Discussion in Pittsburgh, during the discussion of fusion-welded boiler drums. Mr. Fish there said, "Boiler insurance companies are strong proponents of welded construction and do not hesitate to afford insurance on boilers of this type."

Because of the wide circulation of *The Locomotive* to many engineers and companies in the power field, it is most unfortunate that the article was not specific as to the class of welding involved, for this omission may have led many to infer that it also applied to power boilers, thereby disturbing confidence in fusion-welded boiler-drum construction, as sanctioned by the A.S.M.E. Boiler Code and carried out under rigid procedure of control and inspection.

However, the article serves to emphasize the character of much welding that is going into the construction of unfired pressure vessels which are not built in accordance with Par. U68 of the A.S.M.E. Code for Unfired Pressure Vessels, commonly known as Class I vessels. These rules are strict and require, besides other tests, stress-relieving and X-ray examination. This is particularly important as many of these vessels contain fluids and gases at pressures under which rupture would undoubtedly entail loss of life and considerable property damage.

The New York Power Show

The New York Power Show is less than two weeks off. According to present reports as to the number of companies that will be represented, namely, two hundred eighty-five, and the character of the exhibits, it is believed that the show will reflect the general business improvement. It will be recalled that two years ago practically none of the boiler companies and few of the manufacturers of fuel-burning equipment were represented, for at that time there was little activity in the power plant field. Since then, however, both the central station and the industrial power fields have become active, and advances in practice have involved much that is new in design. In view of this many companies that were missing in the 1934 show will again have space, particularly manufacturers of steam generating equipment.

Despite conditions in the Fall of 1934, the attendance was approximately thirty-seven thousand and it is probable that, in view of present conditions, this year's attendance will be larger. From the exhibitor's viewpoint, however, the quality of the attendance is more important than numbers and the success of the show will be judged on this score. With much new construction in the planning or proposal stages it is likely that many will take advantage of the opportunity to see and compare what the exhibitors have to offer before making final selections; hence the quality of the attendance is likely to be up to expectations.

Coal Per Kilowatt-Hour

The average coal consumption of British central stations, as reported by the Electricity Commission, is now 1.57 lb per kw-hr, a figure not far behind that for this country which has remained practically constant at around 1.46 for the past two or three years. The marked improvement in the British figures is traceable to the modernization which got under way in England while we were still in the depths of the depression.

Bearing in mind that the present figure of 1.46 lb per kw-hr includes the numerous old inefficient plants as well as the more modern stations and that the trend toward superposition will improve the economy of many of these older stations by a third or more, one may look for an appreciable reduction in this average figure when the statistics are compiled for 1937, as many of these extensions will go into service early next year.

The spectacular drop in this ratio from 1920 to 1930 was attributable to revolutionary advances in practice as applied to the many new stations built during that period. With application of the law of diminishing returns further improvement must come largely from the modernization of old stations or their replacement by new.

Factors in the Design of Superposed Turbines

By H. L. WIRT, General Electric Co., Schenectady, N. Y.

With the advent of higher steam temperatures creep characteristics of the materials assume increased importance and necessitate a constant check of the various alloy steels in automatic creep-testing furnaces. The design of rotor shells, welded diaphragms and 3600- versus 1800-rpm rotors are discussed, as is also the advance made in hydrogen cooling of the generators.

MANY authoritative articles have been written recently on superposition, discussing the factors involved in adding high-pressure boilers and turbines to existing plants, details of the superposed cycle and the many and varied economic advantages of adding capacity by means of high pressure and high temperature. New turbines from the design viewpoint are required to meet these new conditions.

Back in 1923, the Philo and the Crawford Ave. Stations started a trend toward higher steam conditions by going to the then "risky" pressure and temperature of 600 lb per sq in. and 725 F. Excessive moisture in the last stages was prevented by resuperheating after partial expansion, with its added complication and cost. Turbines in the United States operating on the reheat cycle total approximately 2,000,000 kw.

In 1924 Edgar Station, Boston, followed by Lakeside Station in Milwaukee, pioneered with turbines of the 1200-lb superposed type, and again because of temperature limitations resuperheating of the steam was required. The success with these topping turbines led to the installation of condensing 1200-lb turbines of tandem compound, cross-compound and vertical-compound types for ratings from 25,000 kw to 150,000 kw. Again resuperheating during crossover was required.

With high pressures and temperatures a third stage has now been reached in which turbines use 925 F steam without resuperheating. Two out of every three of the twenty-five large turbines ordered during the past year in this country are of the superposed type, so consideration can well be given to some of the various factors involved

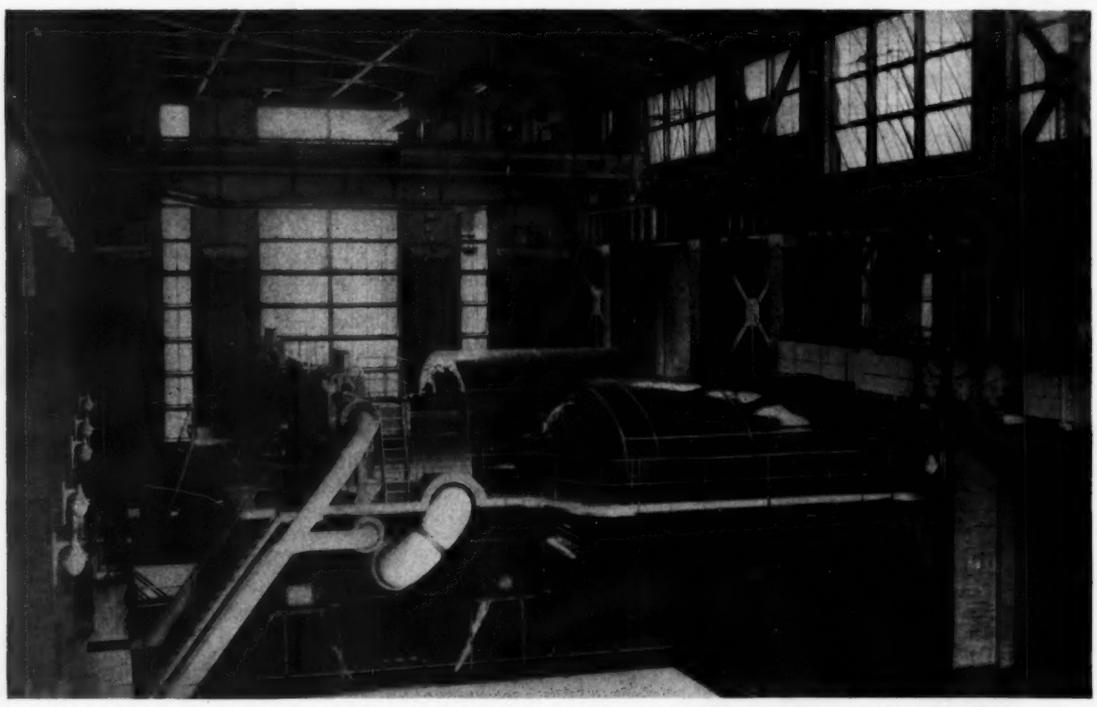

Fig. 1—High-pressure vertical-compound turbine-generators at the Rouge plant of the Ford Motor Co.

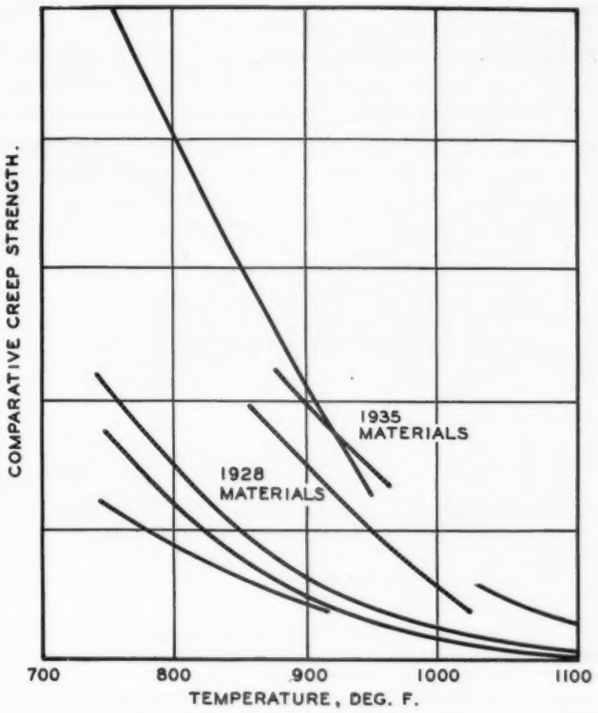

Fig. 2—Typical creep characteristics of certain alloy steels used in turbine construction

in designing topping turbines for pressures and temperatures in the 1250-lb 925-F range.

This trend in the development of the high-pressure turbine-generators is shown by the list[1] of recently installed high-pressure turbines and of superposed turbines under construction:

RECENTLY INSTALLED HIGH-PRESSURE TURBINE-GENERATORS

Kw Rating	Customer	Steam Conditions Lb gage	Deg F	B. P.	RPM	
12,500	Virginia Electric Power Co.	825	825	220	3600	Air-cooled
15,000	Ford Motor Co.	1200	900	260	3600	Air-cooled
110,000	Ford Motor Co.	1200	900	1"	1800	Air-cooled
	(Vertical-compound, double-flow in the low-pressure element)					

TYPICAL SUPERPOSED TURBINE-GENERATORS UNDER CONSTRUCTION

(All are single casing 3600 rpm machines)

60,000	Ohio Power Co., Windsor	1250	925	235	Hydrogen-cooled
60,000	West Penn Power Co., Windsor	"	"	"	Hydrogen-cooled
50,000	Appalachian Elec. Pr. Co., Logan (Am. Gas & Elec. Co.)	"	"	200	Hydrogen-cooled
25,000	Dayton Pr. & Lt. Co.	1200	900	230	Hydrogen-cooled
25,000	Monongahela W. Penn Public Service Co., Rivesville	1200	925	260	Air-cooled
10,000	Nebraska Power Co., Omaha	1200	900	200	Air-cooled
10,000	Consumers Pr. Co., Jackson, Mich.	750	850	210	Air-cooled

Progress in turbine design is well illustrated by the 110,000-kw Ford turbines. The first unit, installed in 1931, was designed for a temperature of 725 F, and the steam, after passing through the high-pressure element, had to be reheated in steam reheaters to 550 F before entering the low-pressure element. In the case of the second machine just installed, the total temperature of 900 F makes reheating unnecessary, and as can be seen in the view of the unit (Fig. 1), the steam passes directly from the high-pressure element to the double-flow low-pressure element.

[1] This list does not include all such turbines—EDITOR.

High-Temperature Materials

The problem of materials presented to the turbine designers is illustrated by Fig. 2. The curves represent certain creep characteristics of different steels containing alloying materials such as nickel, chromium, molybdenum, manganese, etc., to produce a variety of steels suitable for turbine rotors, shells, nozzles, buckets and bolts. They show the relation between stress and temperature for a selected creep and emphasize the problem created by high temperature. Continual study has to be devoted to materials, not only in designing but also during manufacture. New materials are compared by a "step-down" or bolt-relaxation test, and the best of these are placed in aging tests. Thus, a number of automatic creep testing furnaces containing the best materials are in continuous operation and are gradually yielding data on which satisfactory designs can be based. The curves also show that when high-temperature machines are in operation, greater care than ever should be exercised to avoid excess temperature. The turbines are designed, so to speak, for operation on the brink of a satisfactory life curve, and excess temperature will result in abnormal creep and ultimately in disproportionate maintenance.

Turbine Shells

In designing a high-pressure shell such as Fig. 3, it is necessary to keep the stresses within safe limits and use stable shapes that will not distort or crack during expansion and contraction.

The large single-cylinder non-condensing turbines for temperatures above 900 F are designed with a double shell. The leakage from the packing goes into the space between the inner and outer shells at considerably lower pressure and temperature, and thus the outer shell runs relatively cooler and holds a much lower pressure. As shown in Fig. 4, the pressure difference across the inner shell is much less than the initial pressure and therefore the casting can be made thinner. It is also subjected to temperature on both sides and so has the advantage of warming up more quickly and more uniformly. The first-stage nozzles are distributed around the periphery

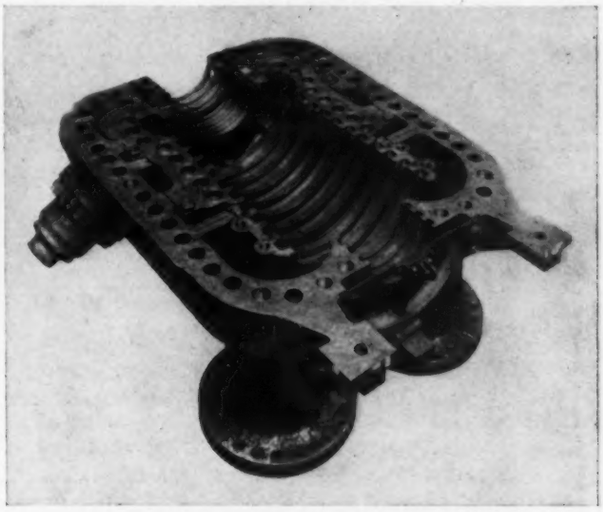

Fig. 3—Inner and outer lower-half shell assembly for high-pressure, high-temperature turbine

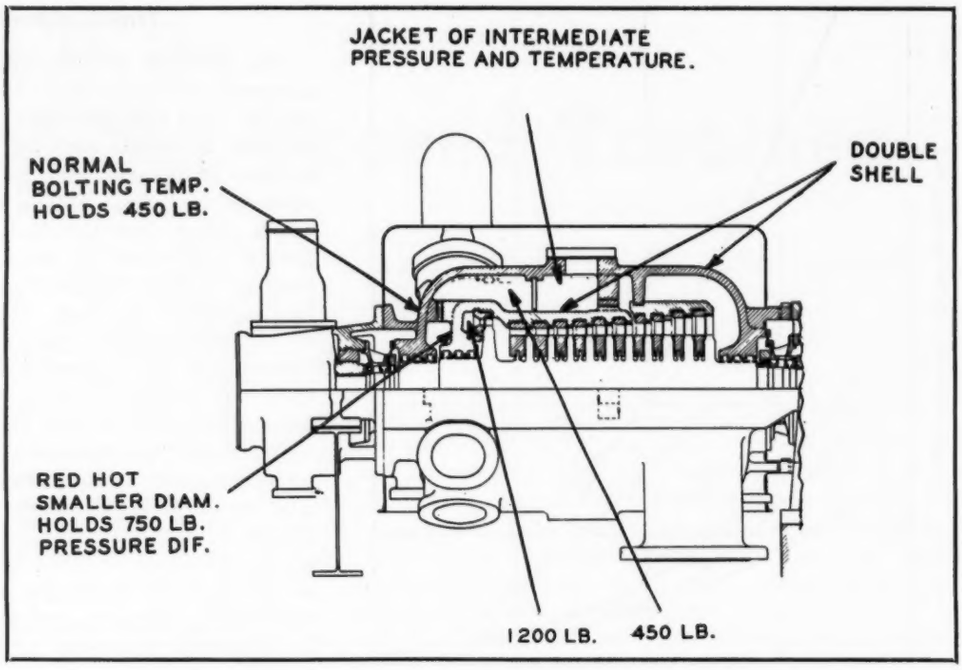

Fig. 4—Double-shell construction indicating differential pressures

of the first-stage shell and are fed by six relatively flexible pipes coming from six control valves leading off from a common manifold, or header, below the turbine room floor. Steam is supplied to this header through two throttle valves, one located at each end. The oil pumps and oil tank are below the floor on the generator end of the machine away from the hot parts in order to lower the fire hazard. The operating gear for the valves is below the floor on the turbine end of the unit and under the valves. The high-pressure oil piping is enclosed in the low-pressure return lines so that any leakage from the high-pressure pipes is enclosed and cannot spray out onto hot surfaces. The control mechanism from the valves is all below the hot pipes.

Rotors

Since 3600 rpm hydrogen-cooled generators are available in large sizes, it follows that this speed is generally used for the turbine rotors, especially as this speed is ideally suited to non-condensing turbines even in the largest sizes as large buckets are not required. A comparison between 3600 and 1800 rpm is given by Fig. 6, which shows the relative size rotors for these rotative speeds for 50,000-kw, 1200 lb, 900 F non-condensing back-pressure turbines exhausting at 200 lb per sq in. The wheels are integral with the shaft, all being machined from a single forging. Sulphur prints on the ends of the forging disclose the structure of the metal and permit locating the shaft centers so that the center line of the finished shaft will coincide with the center line of the micro-structure, thereby giving greater assurance of a straight shaft when hot.

Fabricated Diaphragms

The development attained in the art of fabrication by the use of deposited ductal weld metal to unite complicated machine parts into an integral whole is nowhere more effectively illustrated than in the manufacture of fabricated nozzle diaphragms shown by Fig. 5. The finished diaphragm has great uniformity, high strength and that detailed perfection essential for high efficiency in high-pressure turbine nozzles.

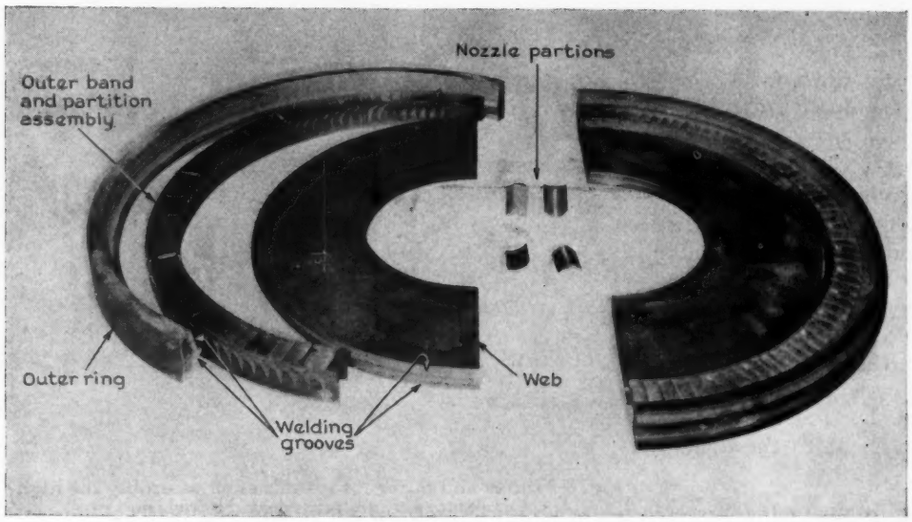

Fig. 5—Turbine diaphragm, the left half ready to be assembled and the right half complete

Generators

The development work on hydrogen cooling of generators has been carried on by the General Electric Company since 1922 when a 3380-kva generator was operated as a hydrogen-cooled machine at the factory. The information obtained was made the basis for the design of a generator especially adapted to hydrogen cooling, which was built and operated in 1928. Considerable experience

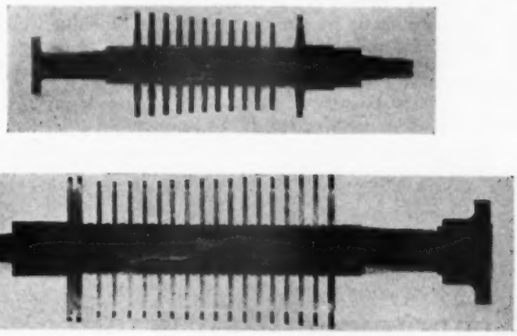

Fig. 6—Comparative sizes of rotors for 3600 rpm and 1800 rpm, each for 50,000-kw, 1200-lb, 900-F units exhausting at 200-lb gage. The upper view represents a 3600-rpm rotor and the lower an 1800-rpm rotor

has also been obtained with a large number of hydrogen-cooled synchronous condensers. Therefore, when the 50,000 kva unit was designed for Logan Station in 1935, hydrogen cooling was employed for the first time on a commercial turbine-generator. It was fortunate that this development was ready, as the 3600 rpm speed is particularly suited for "topping" turbines.

Hydrogen cooling is of particular advantage in high-speed machines because friction and windage constitute the main items of loss, and hydrogen reduces these to approximately one-tenth their value with air. The Logan machine is cooled by water circulated through pads located in the laminations.

Fig. 7 shows a stator frame for a 25,000-kw hydrogen-cooled generator. Fans on the generator rotor circulate hydrogen through the generator and through finned tube coolers mounted in the radial space within the outer shell. The tubes run lengthwise, parallel to the shaft of the

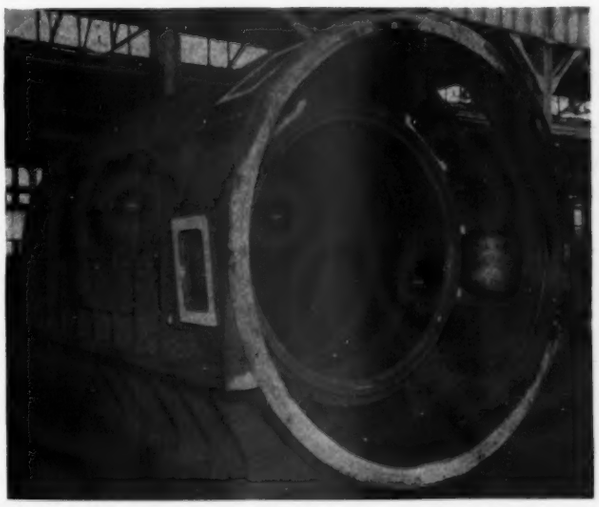

Fig. 7—Armature frame of hydrogen-cooled generator with fin-tube water cooler in place

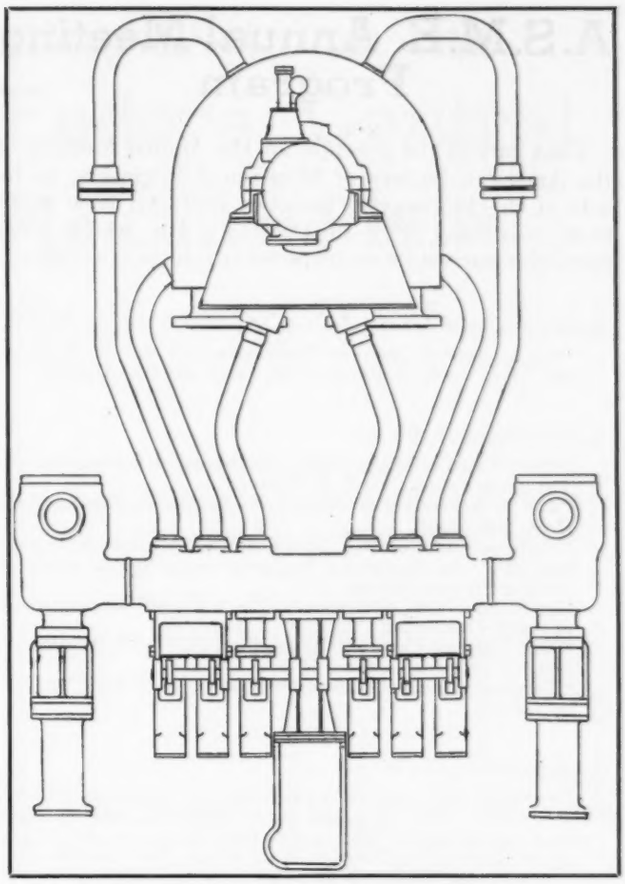

Fig. 8—End elevation of Logan turbine

generator, and hydrogen is brought into the air gap at two or three places along the length of the rotor. The cooling surface is of the familiar air-cooler type. Water boxes at one end are in the form of a 90-deg elbow projecting through the outer shell. The cover plate and water connections can be removed to give access to the tubes for cleaning without disturbing the hydrogen-tight portion of the machine.

Sodium Sulphite for Removal of Oxygen

It seems desirable to expand slightly the last paragraph in the article under this title, appearing on page 25 of COMBUSTION for September, in order to answer questions raised by some readers.

In its hydrated form, sodium sulphite contains only 50 per cent of the active ingredient Na_2SO_3, melts with slight increase in temperature, and deteriorates more readily with formation of sodium sulphate on standing than does the anhydrous form. Thus the anhydrous form is the preferable material to use in power plant work. Commercial anhydrous sodium sulphite contains a small amount of sodium sulphate, iron and caustic soda as impurities. The sodium sulphite content will be well above 90 per cent, usually 95 per cent or above. The additional caustic soda is advantageous. Such a grade contains nothing detrimental in water conditioning work. "Santosite," mentioned in the article referred to, is a commercial anhydrous sodium sulphite of this type.

A.S.M.E. Annual Meeting Program

That part of the program for the Annual Meeting of the American Society of Mechanical Engineers, to be held at the Engineering Societies Building, New York, from November 30th to December 4th, which holds particular interest for steam power engineers, is as follows:

Monday evening, 8 p.m.

"Steamotive—A Complete Generating Unit, Its Development and Test," by E. G. Bailey, A. R. Smith and P. S. Dickey.

Tuesday morning, 9.30 a.m.

"The Creep Curve and Stability of Steels at Constant Stress and Temperature," by S. H. Weaver
"The Interpretation of Creep Tests for Machine Design," by C. R. Soderberg
"Discussion of Research Activities and Progress Reports to Sponsors," by the Special Research Committee on Effect of Temperature on Metals
"Problems in the Collection and Evaluation of Data for Design of Steam-Generating Units," by B. J. Cross
"The Thermal Conductivity of Liquids," by J. F. Downie Smith
"Temperature and Combustion Rates in Fuel Beds," by M. A. Mayers

Tuesday afternoon, 2 p.m.

"Panel Discussion on Cinder Catchers," participated in by W. G. Christy, H. F. Johnstone, C. W. d'Hedberg, Ollison Craig, H. F. Hagen, L. C. Whiton, Jr., Paul Thompson, J. J. Grob, H. P. Hardie, C. S. Messler, M. D. Engle, J. H. Leitch, H. B. Reynolds and Stanley Brown
"The Effect of Installation on the Coefficients of Venturi Meters," by W. S. Pardoe
"Extended Information on Orifice Coefficients," by S. R. Beitler
"Square-Edge Inlet and Discharge Orifices for Measuring Air Volumes in the Testing of Fans and Blowers," by L. S. Marks
"The Modified I. S. A. Orifice with Free Discharge," by M. P. O'Brien and R. G. Folsom

Tuesday afternoon, 4 p.m.

"The Engineering Achievements of George Westinghouse"—a discussion by his former associates

Wednesday morning, 9.30 a.m.

"Undercooling in Steam Nozzles," by J. T. Rettaliata
"Tests of a Large Surface Condenser at Widely Varying Temperatures, Velocities of Inlet Water and Loads," by G. H. Van Hengel

Wednesday afternoon, 2 p.m.

"Superposed Turbine Regulation Problems," by A. F. Schwendner and A. A. Luoma
"Turbine Supervisory Instruments and Records," by J. L. Roberts and C. D. Greentree
"Supervisory Instruments for 165,000-kw Turbine at Richmond Station," by H. Steen-Johnsen

Thursday morning, 9.30 a.m.

"Physical-Property Uniformity in Valve-Body Steel Castings," by A. E. White, C. I. Clark and Sabin Crocker
"Unique Design Features and Operating Experiences at the Port Washington Power Plant," by F. L. Dornbrook
"Symposium on Corrosion-Resistant Metals"
"Review of Existing Psychrometric Data with Relation to Practical Engineering Problems," by W. H. Carrier and C. O. Mackey
"Method of Computing Thermal Properties of Oxygen and Nitrogen, and Derivation of a New Equation of State Therefore," by W. L. DeBaufre and T. A. Filipi
"Leakage of Gases through Narrow Channels," by A. Egli

Thursday afternoon, 2 p.m.

"Symposium on Corrosion-Resisting Metals"—continued
"Reactions of Sodium Sulphite under Boiler Operating Conditions," by F. G. Straub
"Progress Report on Embrittlement and Dissolved Oxygen Determination"
"Discussion of Boiler Feedwater Problems"

Thursday evening, 8 p.m.

"Symposium on Corrosion-Resisting Metals"—final session
"The Steam Turbine in the United States"
I. "Development by the Westinghouse Machine Company," by E. E. Keller and F. Hodgkinson
II. "Early Development by the Allis-Chalmers Manufacturing Company," by A. G. Christie
III. "A Brief History of Steam-Turbine Development by the General Electric Company," by E. L. Robinson

The Annual Banquet will be held at the Hotel Astor on Wednesday evening.

Economizer Maintenance

Operating company statements contained in the recent E. E. I. Prime Movers Committee Report on "Boilers, Economizers, Air Heaters and Piping" give experiences with economizer maintenance and the methods employed for removal of soot accumulations on the exterior surfaces of the tubes.

Inasmuch as the soot blowers are effective in removing soot accumulations only from those tubes in line with and comparatively close to the nozzles, it has been found necessary in many cases to supplement this with washing or hand lancing. Several companies have adopted periodic washing of the exterior surfaces with water sprays. One company does this three times a year and has devised an intermittent, clock-operated sprinkler for this purpose. The fresh water which is sprinkled over the tubes soaks into the soot which becomes loosened and falls into the hopper. Three days are required for each washing.

One company found it necessary to discontinue washing because of corrosion, but another company in the same region overcame the corrosion problem by adopting the practice of washing just before the boiler is brought on the line and then passing hot feedwater through the economizer. In still another case, where high-sulphur coal was burned, corrosion was overcome by changing to washed coal.

Leakage at the rolled ends where tubes enter the headers has set up local external corrosion in a number of cases, due to differential expansion. Rerolling was not always effective.

In one installation where the header space was packed with soft plastic to act as a gas seal, any slight tube leak was found to saturate this material and set up corrosion. The trouble was overcome by removing this material and coating the metal surfaces with an emulsified asphalt paint, at the same time making the casing around the headers gas-tight to prevent air leakage. Sheet packing was found more satisfactory for flat seat headers than metal or metallic gaskets.

In general, fouling of the external tube surfaces has been more common with stoker firing than with pulverized coal.

Equipment and Operating Data on the Federal Central Heating Plant, Washington, D. C.*

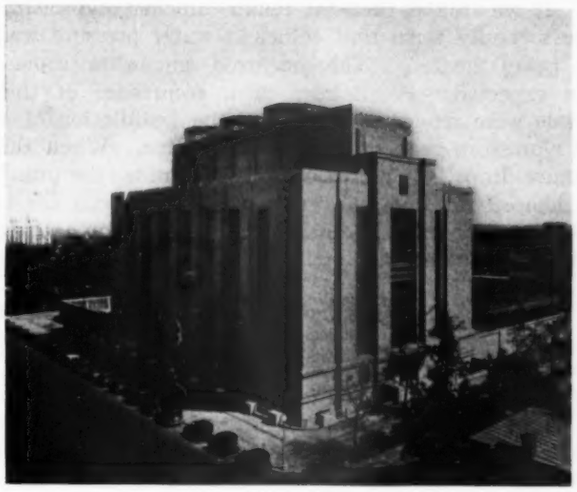

Fig. 1—Exterior View of Central Heating Plant

An account of the operating experiences and performance of the Central Heating Plant which supplies steam to the Triangle Group of new federal buildings in Washington, D. C. Test results and a list of the equipment in the plant are included.

By J. F. BARKLEY† and CHARLES A. PETERS, Jr.‡

THE Federal Central Heating Plant at Washington, D. C., put into operation during January 1934, consists essentially of six 400-lb pressure, cross-drum sinuous-header boilers, each of 25,243 sq ft heating surface, equipped with underfeed stokers having a projected grate area, including the clinker pit, of 490 sq ft. At present it serves seventy-one buildings, the locations of which are shown in Fig. 2. Steam is generated at 200-lb gage pressure and distributed at that pressure, the lowest line pressure reached at any point being 187-lb gage. Fig. 3 shows a cross-section of the plant; Table I gives some typical test data and Table II lists the principal equipment.

The plant was constructed by the Procurement Division of the Treasury Department and is operated by the Branch of Buildings Management, National Park Service, Department of the Interior. The total plant and distributing system cost, exclusive of engineering, was as follows:

Rust Engineering Company	General construction	$1,489,900.00
McDermot Bros.	Excavation	14,940.00
Combustion Engineering Company	Boilers, stokers, forced- and induced-draft systems	639,647.00
Northeast Pipe & Const. Co.	Tunnels and distribution	1,194,826.50
Ellis Bros.	Tunnels and distribution	299,400.00
L. E. Dockstader	Miscellaneous	32,000.00
Research Corporation	Precipitators	374,600.00
		$4,045,313.50

The United Engineers & Constructors, Inc., Philadelphia, Pa., served as consulting engineers on this project.

About 115,000 tons of coal are burned per year. The highest average hourly steam load for 24 hr to date has been 639,000 lb per hr and the maximum hourly load to date 735,000 lb per hr. The boilers are usually operated at loads from 150,000 to 220,000 lb per hr each. Average overall boiler operating efficiency is about 80 per cent.[1] The quantity of coal burned per square foot of projected stoker area varies from about 30 to 45 lb per hr. The coal used for the past year was a Pennsylvania 3/4-in. slack coal costing $4.60 delivered, of the following average analysis:

H_2O—"as received"	2.8%
Volatile—"dry basis"	25.2%
Ash—"dry basis"	8.8%
Sulphur	1.3%
Btu—"as received"	13840
Btu—"dry coal"	14240
Ash fusion	2710 F
Iron content of ash expressed as Fe_2O_3	Approx. 15%

The operating cost of steam delivered at the buildings, with no taxes, amortization, etc., included, varies from about 30 cents per 1000 lb in the winter to about 73 cents per 1000 lb in the summer, at which time only one boiler is operated at low loads. The following shows the division of the costs:

	Winter	Summer
Fuel per 1000 lb of steam delivered	$0.2661	$0.3173
Labor " " " " " "	0.0307	0.2442
Supplies " " " " " "	0.0061	0.1640
Standby power " " " " " "	0.0005	0.0036
Total	$0.3034	$0.7291

The material maintenance on the stokers has been very low, averaging about 2.55 cents per ton of coal burned over the period of a year. Upon one occasion a stoker was operated for 8 mo. without any shut-down for repairs.

In putting the plant into operation, the usual process of breaking in men and equipment was experienced.

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† Supervising Engineer, Fuel Economy Service, U. S. Bureau of Mines, Washington, D. C.

‡ Assistant Director, National Park Service, Washington, D. C.

[1] Neither economizers nor air heaters are installed—EDITOR.

The breaking in of a large underfeed stoker having certain newly-designed features, the developing of inexperienced men and the determining of the type of coal best suited for use all came together, resulting in difficulties. Stoker rams seized, bell-cranks and main cranks were broken, tuyères and extension grates were burned and sifting difficulties experienced; as a result certain modifications of the stoker were found necessary. Some coals would not stay on the grates and there was much blow-over. Other coals clinkered badly, forming at times a mass of clinker 6 to 8 ft long, 30 in. wide and 12 in. thick, weighing about 900 lb. Such troubles were gradually ironed out. Different tolerances were used on the rams, the extension grates were changed somewhat in design, the proper proportioning of the air to the different zones of the stoker was learned, sifting troubles were eliminated, the men became experienced and the type of coal suitable for the equipment was determined. In its purchase, the following analytical limits at present are used, the final coal being chosen subject to operating tests:

Maximum H_2O—"as received"	4.0%
Maximum volatile—"dry basis"	26.0%
Maximum ash—"dry basis"	10.0%
Minimum Btu—"dry basis"	13900
Ash fusion—2500 F. for ash content up to 8% inclusive	
" " —2650 F. " " " above 8%	

If iron content of ash, expressed as Fe_2O_3, is over 20% the coal can be rejected.

The turbine and reduction-gear units of the hydraulic drives on the stokers at first were undesirably noisy, gave varying speeds and spasmodic pressures and required considerable attention. A new type of governor was provided and the units were tuned up satisfactorily. At the start of operation, as many as six or seven boiler-gage glasses per day began breaking. Providing an expansion loop on the blow-down connection and using the highest grade glass disposed of this difficulty.

In the course of time the pipe line carrying the ashes from the pump some 400 ft to the ash hopper plugged up. It was found that the pump impeller and casing were so badly worn that sufficient water pressure was not being created. This occurred somewhat sooner than expected. Possibilities of a recurrence of this trouble were rendered remote by the installation of a water-pressure gage on the discharge line. When the pressure drops to a predetermined minimum, the pump is taken off the line and repaired. Much better life is now being secured in the impeller and casing by coating them at the plant with stellite by means of an electric arc.

Considerable difficulty was experienced with the Bailey control which was a new design using compressed air. This was particularly true of the control of the fuel, which was further augmented by inexperience in stoker operation. Parts of the system were redesigned. It was found necessary to run the fans and dampers in parallel on both the forced-draft and the induced-draft fans. During the past winter, satisfactory operation was attained on three boilers, all working on the master control, and it is believed that next winter the remaining boilers will also operate satisfactorily in this manner.

Boiler feedwater conditioning has been quite satisfactory. About 50 ppm of phosphate and 30 ppm of sodium sulphite are carried in the boiler water. Tests for oxygen content rarely show more than 0.04 ml of

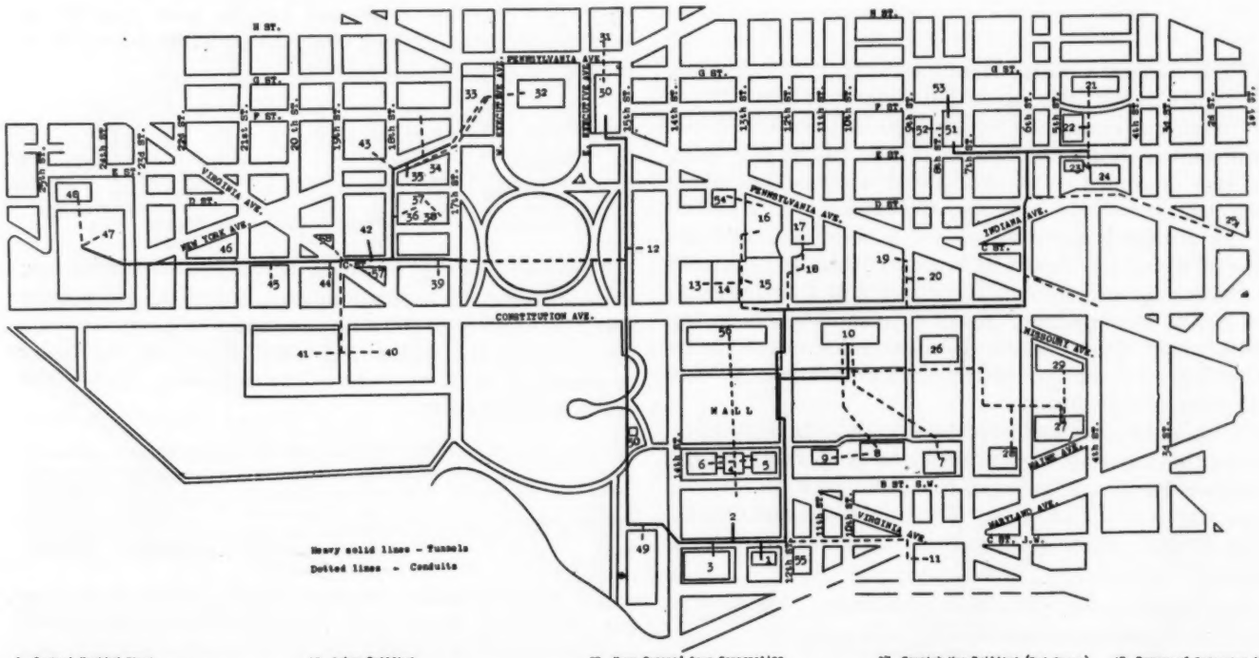
Heavy solid lines - Tunnels
Dotted lines - Conduits
1 Central Heating Plant
2 Agriculture Extension Building
3 Bureau of Engraving & Printing (Warehouse)
4 Agriculture Administration Building
5 Agriculture East Wing
6 Agriculture West Wing
7 Army Medical Museum
8 Old National Museum
9 Freer Art Gallery
10 New National Museum (Group)
11 Federal Warehouse & Extension
12 Commerce Building
13 Labor Building
14 Federal Auditorium
15 Inter-State Commerce Building
16 New Post Office Building
17 Old Post Office Building
18 Internal Revenue Building & Extension
19 Justice Building
20 Archives Building
21 Old Pension Office Building
22 New Police Court Building
23 District Court of Appeals Building
24 District Supreme Court Building
25 Home Owners' Loan Corporation
26 Building P (Temporary)
27 Building E
28 Old Bureau of Fisheries Buildings (Group)
29 Vaults & Mattress Factory (Group)
30 Treasury Building
31 Treasury Annex
32 White House & Executive Offices
33 State Building
34 Corcoran Gallery of Art
35 Walker Johnson Building
36 World War Building-(Red Cross)
37 Spanish War Building (Red Cross)
38 Civil War Building (Red Cross)
39 Pan American Building & Annex
40 Navy Building
41 War Building
42 New Interior Building
43 Old Interior Building
44 Public Health Building
45 Federal Reserve Board Building
46 Potomac Park Apartments
47 Naval Hospital
48 Institute of Health Building
49 Bureau of Engraving & Printing (Group)
50 Monument Lodge
51 Old Land Office Building
52 801 E Street N.W.
53 Civil Service Building
54 1500 E Street N.W.
55 Economics Building
56 Department of Agriculture Green Houses & Shops
57 Temporary Building No. 2
58 Temporary Building No. 7

Fig. 2—Showing location of buildings served by the Central Heating Plant

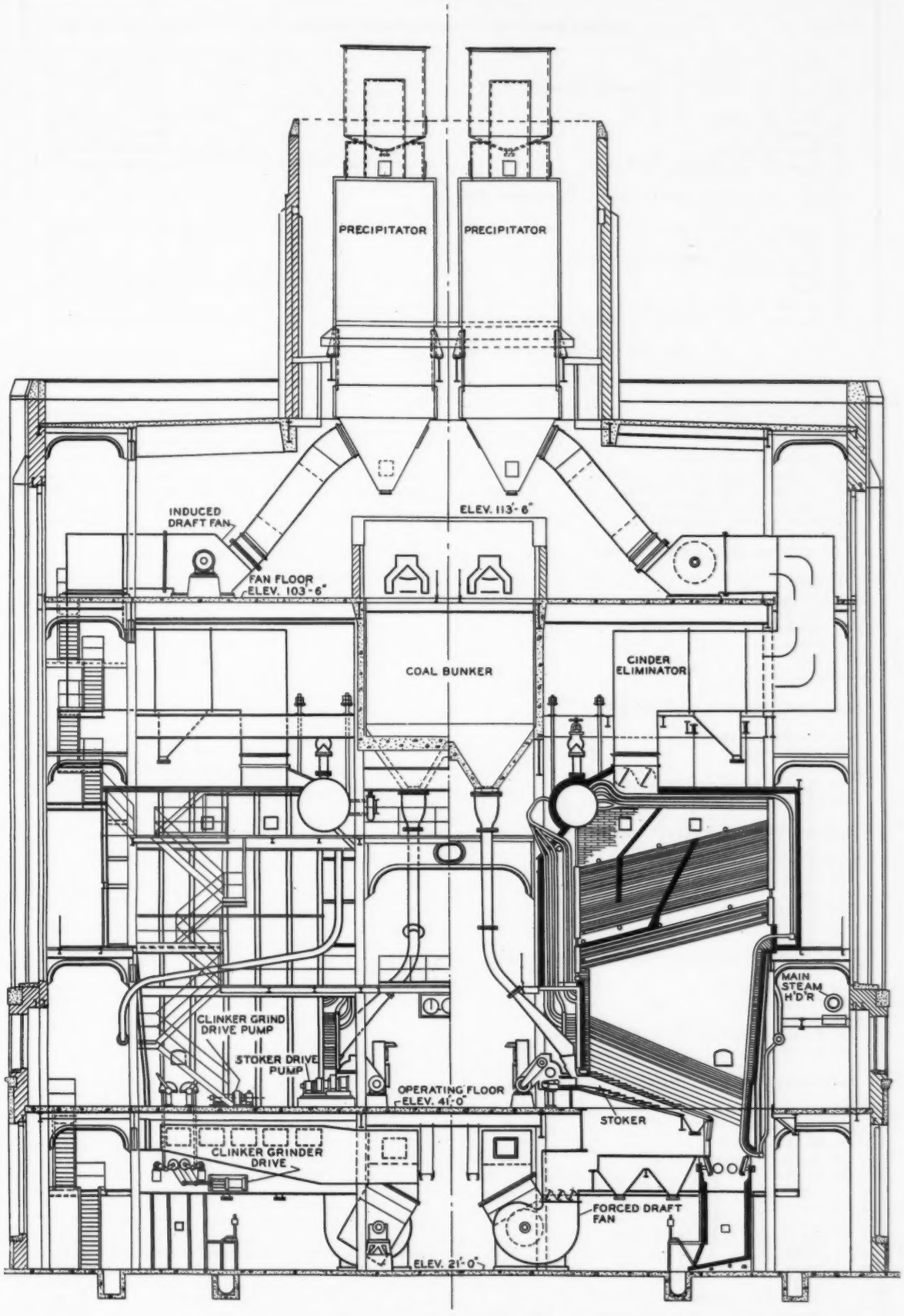

Fig. 3—Cross-section through boiler room

TABLE I

Typical Test Data - Federal Central Heating Plant

	General Information		
1	Date of test	March 1935	14 & 15
2	Location	Washington, D. C.	
4	Type of boiler	Walsh & Weidner Cross-drum	
10	Type of fuel burning equipment	Inclined Underfeed Stoker with Clinker Grinder	
	Description, Dimensions, Etc.		
13	Boiler heating surface	sq ft	25243
14	Water wall surface	sq ft	1815
18	Total steam-generating unit surface	sq ft	27058
20	Grate surface	sq ft	490
23	Fuel	Medium Volatile Bituminous Coal	
24	Volume of combustion space	cu ft	9800
26	Furnace volume per sq ft boiler heating surface	cu ft	0.39
	Fuel and Gas Analyses and Data		
	Fuel Proximate Analysis (as Fired)		
27	Volatile matter	per cent	24.4
28	Fixed carbon	per cent	61.8
29	Ash	per cent	10.1
30	Moisture (as fired)	per cent	3.7
31	Heating value per lb (as fired)	Btu	13410
32	Heating value per lb (dry)	Btu	13920
33	Fusion temperature of ash	F	2530
34	Size of coal as fired		3/4" slack
	Fuel Ultimate Analysis (as Fired)		
35	Carbon	per cent	76.4
36	Hydrogen	per cent	4.5
37	Oxygen	per cent	2.6
38	Nitrogen	per cent	1.3
39	Sulphur	per cent	1.4
40	Ash	per cent	10.1
40a	Moisture	per cent	3.7
	Flue Dust Proximate Analysis (Dry)		
27a	Volatile matter	per cent	3.3
28a	Fixed carbon	per cent	22.8
29a	Ash	per cent	73.9
31a	Heating value per lb	Btu	3230
39a	Sulphur	per cent	0.9
	Cinders Proximate Analysis (Dry)	per cent	1.8
27b	Volatile matter	per cent	1.8
28b	Fixed carbon	per cent	46.8
29b	Ash	per cent	51.4
31b	Heating value per lb	Btu	6740
39b	Sulphur	per cent	0.5
	Front Stoker Siftings Proximate Analysis (Dry)		
27c	Volatile matter	per cent	24.8
28c	Fixed carbon	per cent	62.3
29c	Ash	per cent	12.9
31c	Heating value per lb	Btu	13530
39c	Sulphur	per cent	2.5
	Rear Stoker Siftings Proximate Analysis (Dry)		
27d	Volatile matter	per cent	24.9
28d	Fixed carbon	per cent	64.2
29d	Ash	per cent	10.9
31d	Heating value per lb	Btu	13850
39d	Sulphur	per cent	2.0
	Gas		
42	Gas analysis, boiler outlet:		
	CO_2	per cent	15.73
	O_2	per cent	3.13
	CO	per cent	0.03
	N_2 (by difference)	per cent	81.11
46	Dry gas per lb fuel, boiler outlet (as fired)	lb	12.01
50	Air supplied per lb fuel, boiler outlet (as fired)	lb	11.55

TABLE I (Cont'd)

Pressures and Drafts			
52	Steam pressure by gage, boiler	lb per sq in.	200.3
56	Air pressure in stoker wind-box	in. of water	4.06
56a	Air pressure at stoker tuyeres - top zone	in. of water	2.06
56b	Air pressure at stoker tuyeres - center zone	in. of water	2.12
56c	Air pressure at stoker tuyeres - bottom zone	in. of water	2.20
56d	Air pressure at stoker overfeed section	in. of water	2.11
56e	Air pressure at clinker grinder pit	in. of water	1.76
57	Draft in furnace	in. of water	-0.378
58	Draft at boiler outlet	in. of water	-1.213
59	Draft in uptake at fan	in. of water	-2.795
Temperatures			
62	Moisture in steam	per cent	0.17
66	Temperature of air surrounding boiler, (t_1)	F	76
69	Temperature of air for combustion, (t_4)	F	118
71	Temperature of gases leaving boiler, (t_6)	F	603
74	Temperature of feedwater entering boiler, (t_9)	F	120.7
Hourly Quantities			
78	Duration of test	hr	13.343
79	Fuel per hour (as fired)	lb	19812
80	Fuel per hour dry	lb	19079
81	Fuel as fired per sq ft of grate per hour	lb	40.4
82	Fuel as fired per retort per hour	lb	1321
83	Dry fuel per sq ft of grate per hour	lb	38.9
84	Dry fuel per retort per hour	lb	1272
85	Combustion space per lb coal per hour (as fired)	cu ft	0.49
86	Refuse from ash pit per hour	lb	1283
86a	Flue dust per hour	lb	383
86b	Cinders per hour	lb	250
86c	Front stoker siftings per hour	lb	15
86d	Rear stoker siftings per hour	lb	37
87	Actual water per hour	lb	194561
Unit Quantities			
90	Heat absorbed by water and steam in boiler	Btu per lb	1108.7
Hourly Quantities (continued)			
94	Rate of heat absorption in boiler	kB per hr	215710
Refuse, Flue Dust, Cinders and Stoker Siftings			
98	Refuse from ash pit, per cent of fuel (as fired)	per cent	6.5
98a	Flue dust, per cent of fuel (as fired)	per cent	1.9
98b	Cinders, per cent of fuel (as fired)	per cent	1.3
98c	Front cinder siftings, per cent of fuel (as fired)	per cent	0.1
98d	Rear stoker siftings, per cent of fuel (as fired)	per cent	0.2
99	Percentage of combustible in refuse	per cent	12.2
100	Carbon burned per lb fuel (as fired)	lb	0.741
Evaporation			
101	Rate of heat absorption per lb fuel (as fired)	kB	10.888
102	Rate of heat absorption per lb fuel (dry)	kB	11.306
103	Rate of heat absorption per sq ft of steam-generating unit surface per hr	kB	7.972
Efficiency			
104	Efficiency of steam-generating unit	per cent	81.2

Heat Balance of Stationary Steam-Generating Unit

		Btu per lb fuel (as fired)	Per cent
1105	Heating value of fuel	13410	100.0
1107	Heat absorbed by water and steam in boiler	10888	81.2
1110	Heat loss due to moisture in coal	48	0.3
1111	Heat loss due to water from combustion of hydrogen	522	3.9
1113	Heat loss due to dry chimney gases	1519	11.3
1114	Heat loss due to incomplete combustion of carbon	14	0.1
1115	Heat loss due to unconsumed combustible in refuse from ash pit	170	1.3
1115a	Heat loss due to unconsumed combustible in flue dust	63	0.5
1115b	Heat loss due to unconsumed combustible in cinders	85	0.6
1115c	Heat loss due to unconsumed combustible in front stoker siftings	11	0.1
1115d	Heat loss due to unconsumed combustible in rear stoker siftings	26	0.2
1116	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	64	0.5

oxygen per liter of water from the deaerating heater. Alkalinity and sulphate concentrations are carried to maintain correct alkalinity and caustic embrittlement ratios. The steam is of low CO_2 content and is washed by the incoming feedwater, using gratings designed by Combustion Engineering Company.

There has been no scale formation whatever in the boilers, and no outage of boiler equipment resulting from any feedwater condition. No boiler tubes have been replaced. Some difficulty was experienced with an accumulation of sludge in the continuous blowdown lines due to the necessity of throttling to maintain proper concentrations in the boiler. A routine of opening wide the valves for a few minutes each day on boilers in service and of cleaning the lines with steam on idle boilers has eliminated this trouble. Previous to the use of Na_2SO_5, slight indications of oxygen corrosion were found in the top seven rows of tubes, this being worse in the top tubes, and gradually decreasing to about the eighth row, where there were no evidences of corrosion. This was considered to be due to steam pocketing in these upper tubes, resulting from sluggish or reversed water circulation. Small amounts of oxygen getting through the deaerating heater were liberated at the steam-water interface and marked the tubes. Since using the Na_2SO_3, the corrosion has ceased. Some corrosion occurred in the boiler drums during periods of idleness, for upon a few occasions, the boilers were taken off the line and allowed to stand several days with the water at the operating gage glass position. This resulted in pitting at the water line, possibly due to air getting in the drums after the boiler pressure had dropped below atmospheric, the steam condensing in the drum. Idle boilers are now regularly completely filled with water. To condition the water in an idle boiler properly and also to establish uniformity throughout the boiler water satisfactorily required certain new arrangements. Therefore, suitable piping connections are to be made to permit passing through the idle boilers continuous blowdown from boilers in service, so as to provide an oxygen-free water properly conditioned. This will also keep the boilers slightly warm and under a slight pressure.

In the maintenance of the steam distribution system, the principal difficulties have been with bypass valves and traps, and the diaphragm type of expansion joint.

Table II. Equipment Details of the Federal Central Heating Plant, Washington, D. C.

Boilers and Furnaces

Combustion Engineering Company Inc. Six 25,243-sq ft cross-drum, sinuous header, straight-tube type; 400-lb pressure, 45 tubes wide, 5 tubes high lower bank, 16 tubes high upper bank, tubes 4 in. O.D. Welded drums, 60 in. inside diameter, 35 ft 4 3/8 in. long, plate thickness 19/16 in. Eleven inclined water-wall tubes on each side wall paralleling stoker, 7 in. c to c; forty-five perpendicular rear wall tubes 7 in. c to c. Furnace width 26 ft 6 in.; volume 9800 cu ft. Suspended refractory walls, air-cooled except at rear wall. Three furnaces American Arch Co.; 3 furnaces M. H. Detrick Co. Lower 7 rows of side water-wall tubes covered with cast steel blocks, remaining 4 upper rows bare. Rear water-wall tubes bare. Heat release ranges from about 21,000 to 31,000 Btu per cu ft per hr.

Stokers

Combustion Engineering Company Inc. Inclined underfeed multiple-retort type with double-roll clinker grinder; 15 retorts, 38 tuyères, 3 ft overfeed extension grate; 398 sq ft projected grate area, or 490 sq ft including grinder pit. Four secondary rams adjustable together with extension grate for length of travel. Three independently controlled air zones (front, center and rear) under tuyères, an extension grate air zone and a clinker-pit air zone.

Stoker Drive

American Engineering Company, Hele-Shaw transmission; speed 750 rpm; pressure 450 lb per sq in. Pump driven by 30-hp Elliott turbine-gear, 3320 to 800 rpm. Clinker grinder driven by Sturtevant turbine at 1150 rpm. American Fluid Motors Company Hele-Shaw pump, pressure 1000 lb per sq in.

Boiler Accessories

Feedwater regulators	Bailey Meter Company; 2 per boiler
Water columns	"Yarway" (Yarnall-Waring Co.); 2 per boiler
Non-return valves	Pittsburgh Foundry & Constr. Co.
Safety valves	Consolidated Ashcroft Hancock Co.; 7 per boiler
Blowoff valves	"Yarway" (Yarnall-Waring Co.); 6 per boiler
Soot blowers	Diamond Power Specialty Corp.; 12 nozzles per boiler

Air and Products of Combustion

Forced-draft fans—Sturtevant "Turbovane" fan driven by 128-hp, 1200 rpm Sturtevant turbine. Combined throttle and fan-outlet damper control.

Cinder catchers—Green Fuel Economizer Company

Induced-draft fans—Sturtevant type driven by two 60-hp Westinghouse induction motors. Combined speed and boiler damper control.

Precipitators—Cottrell, two units per boiler operating under stub stack.

Coal and Ash Handling

Two railroad tracks holding 46 cars; 3 electric car shifting capstans (Winch and Crane Company). Two track hoppers, 2 apron feeders, 100 tons per hr each, driven by 5 hp Westinghouse motors with Jones reduction gears. One belt conveyor 100 tons per hr, 30 in. × 239 ft, 200 ft per min driven by 15-hp Westinghouse motor with Jones reduction gear. Bradford breaker driven by Westinghouse 40-hp motor with reduction gear. Two skip hoists, 100 cu ft, 100 tons per hr, each, C. O. Bartlett & Snow Co. Two belt conveyors, 100 tons per hr each, fed by two small feeder conveyors over two Merrit Scale Mfg. Co. belt scales. Two 100-ton per hr belt conveyors over coal bunkers. Capacity of bunkers 1200 tons. On one boiler only, 3 Richardson automatic dumping scales, 200 lb per dump. Fairfield coal spreaders, three per boiler to stoker hoppers. Belt conveyor to storage yard 100 tons per hr. Storage yard crane, 10-ton Whiting with 3-cu yd grab bucket. Storage yard capacity 9000 tons at usual height. Reclaiming belt conveyor 100 tons per hr, 200 ft per min.

Ash and Dust Conveyors

Allen-Sherman-Hoff "Hydrojet" ash conveyor. From the ash hopper the ashes are sluiced to the sump through an ash grinder and then pumped out by two vertical 1650-gpm "Hydroseal" units operating at 125 ft head. The ash is pumped approximately 400 ft through 8 in. ascolite pipe to a 100-ton ash-receiving hopper. Sluice water is pumped back by two recirculating pumps of 1500 gpm capacity under 289 ft head, driven by 200-hp Westinghouse motors. An Allen-Sherman-Hoff "Hydrovac" system, about 10 in. vacuum, collecting dust from stoker sifting hoppers, cinder catcher and precipitators, hose connection outlets are provided.

Water

Washington city water of about 8 gr hardness is supplied to a Cochrane lime and soda softener rated at 70,000 gph; to four horizontal Cochrane filters of 34,200 gph each charged with "nonsilite"; and to a Cochrane deaerating heater of 930,000 lb per hr capacity. Condensate return to receiving tank; two 750 gpm condensate pumps. Concrete receiving tank, 1,500,000-lb capacity, takes overflow from condensate receiving tank and deaerating heater. Pumped back through continuous blowdown heat exchanger to deaerating heater by two vertical sump pumps. Steam to the deaerating heater comes from the house turbines and plant auxiliaries, from the flash tank of the continuous blowdown, and from the main steam line automatically valved to hold 2 lb pressure. Steam is led from the deaerating heater to the sedimentation tank of the softener. Filter backwash is handled by a 2800-gpm DeLaval pump operating against 40-ft head at 1760 rpm and driven by a 40-hp Westinghouse motor. Boiler feed from the deaerating heater is handled by two 4-stage Frederick 1500 gpm, 675-ft head, 2200 rpm boiler feed pumps driven by 324-hp Westinghouse turbines and one 4-stage Frederick 400 gpm 675-ft head pump driven by a 100-hp Westinghouse motor. At the boiler feed pump inlet the water is treated with Hagan phosphate and Na_2SO_3. There are also two 750 gpm Frederick house service pumps, one "Hydroseal" general sump pump and one Frederick fire pump of 1000 gpm against 196 ft head.

Instruments and Control System

Boiler indicating steam gages—Ashton.

Draft gages: Bailey indicating, 9 per boiler at stoker wind-box, overfeed section, furnace, boiler outlet, uptake at fan; stoker top tuyère zone, center tuyère zone, bottom tuyère zone, clinker pit section.

General recording and control meters—Bailey.

Bailey two-pen control system using air pressure. Control of forced-draft fan turbine speed and fan damper, stoker speed through hydraulic drive and induced-draft fan motor and boiler-outlet damper, based on main line steam pressure with master control. Compressed air supplied by two Ingersoll-Rand compressors driven by General Electric motors.

Electrical Equipment

Two house turbine-generators, Westinghouse 1250 kva 80 per cent pf 3600 rpm 2300-volt three-phase 60-cycle operation at 200-lb steam pressure and exhausting at 4 lb. Main exciter 15 kw. Pilot exciter, 1.5 kw, supplies field current, controlled by main line voltage regulator, to main exciter. Switchboards—General Electric except Westinghouse voltage regulator panel. Three transformers, General Electric,—150 kva 2300 volts to 208 volts. Local public utility standby for lights, boiler-feed pump, sump pump, Bailey control air compressors and elevator. General Electric kilowatt-hour meters, Westinghouse recording demand meter. Split phase for lights.

Piping and Valves

Piping and valves for high-pressure steam, high-pressure boiler feed, boiler blowoff, high-pressure drips, high-pressure instrument connections, 400-lb standard. Remaining, 125-lb standard. In general, pipe joints are welded. On high-pressure lines, Van Stone flanged joints are used. Valves supplied by Chapman, Edwards, Powell, Vogt.

Insulation

High-pressure steam piping, 5 in. diameter and over, has 4 in. molded sectional magnesia covering; less than 5 in. diameter has 3 in. magnesia; flanges, 2 in. Low-pressure steam piping has 2 in. magnesia and the flanges are not covered. Insulation furnished by the Philip Carey Company.

Steam Distribution

About 80,000 ft of steam piping is installed in tunnels and conduit. This is of 400-lb standard. All pipe joints, 1 1/2 in. pipe or larger, are welded. Van Stone type, flanged joints are used for valves and expansion joints. Expansion loops of corrugated pipe are used where possible; otherwise slip tube externally and internally guided expansion joints are employed for pipe lengths 60 ft or over, and the packless diaphragm type for shorter lengths. These were supplied by the American District Steam Co. There are about 18,000 ft of tunnels ranging from 4 ft wide by 6 ft 6 in. high to 8 ft wide by 7 ft high for main steam piping. High-pressure steam piping is insulated with 3 in. of felted asbestos, and low pressure with 2 in. This was supplied by Johns-Manville Co.

Heat Losses in Flue Gases of Stoker-Fired Boilers

By Dr. A. H. MOODY, Chief Chemist and

J. A. HARRINGTON, Assistant Chemist

The New York Edison Company, Inc.

Boiler efficiency tests always include in the heat balance an item of heat loss due to radiation and unaccounted for. When carbon monoxide is present in the flue gases the ordinary Orsat analyzer is not sufficiently accurate to evaluate correctly the heat loss therefrom. One undetermined element frequently mentioned is the loss due to unburned hydrocarbons. By means of an extremely accurate laboratory method of analysis both the carbon monoxide and the unburned hydrocarbons have been determined. It was found that heat losses due to the latter are insignificant although directly related to the carbon monoxide values. Carbon monoxide in the flue gas under best fuel bed conditions is related to excess air. The heat loss due to carbon monoxide quickly runs into high values when the fuel bed is allowed to suffer clinkers, holes, poor air distribution or heavy feeding.

THE object of this investigation was to determine the losses due to combustible gases leaving the boiler at operating conditions; what factors influence these losses and their relationship; and whether the present excess air value now employed is entirely satisfactory from a combustion standpoint. When preliminary tests indicated an appreciable oxidation of carbon monoxide through the economizer, efforts were made to prove this point and to determine its extent.

The unit used for all these tests is a 1256-hp Springfield boiler with water-cooled sidewalls, having a furnace volume of 6500 cu ft and a projected grate area of 378 sq ft. The stoker is a single-ended, underfeed Taylor type, 33 tuyères long and 14 retorts wide. This particular boiler was used because previous routine CO_2 traverses had shown considerable stratification. Consequently, these results show what might be expected under less desirable conditions.

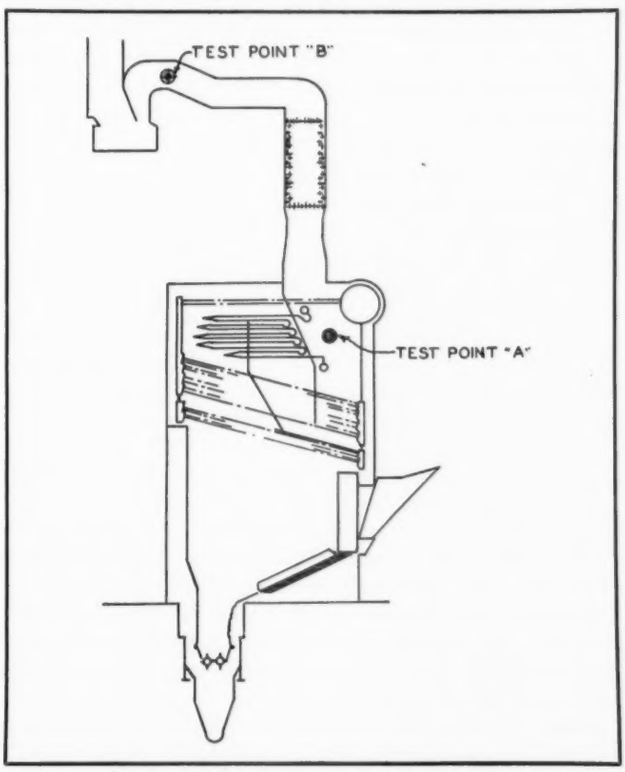

Fig. 1—Indicating test points on boiler

All tests were run at two-hundred per cent boiler rating with the stoker burning about thirty pounds of coal per square foot of projected grate area per hour.

Method of Sampling

It was decided to sample the gases by traversing at the boiler outlet just below the drum and at the economizer outlet duct just before the cinder catcher; (see Fig. 1). Each of the four sampling tubes consisted of an iron pipe $^1/_2$ in. inside diameter, and 12 or 24 ft in length, through which ran a long glass tube extending three inches beyond each end of the iron pipe. A rubber stopper was fitted into the cold end of the sampling pipe to hold the glass tube in place and to keep air from being drawn into the pipe. A 6-in. capped nipple was provided for one end of the iron pipe to protect the glass when not in use. In obtaining average flue gas samples the tubes were moved so that ten equidistant points would be sampled in one traverse.

Gas samples were collected in large aspirator bottles of approximately twenty-two liter capacity by filling them with water containing 0.1 per cent HCl and allowing

the water to drain through a hose. The bottles were calibrated volumetrically and marked with ten divisions of equal volume to correspond to the ten points in the traverse.

Apparatus Employed

Fig. 2 shows the laboratory combustion train in which unburned carbon and hydrogen compounds were determined. A few points need explanation here, but its operation will be covered under "laboratory procedure." The fused quartz combustion tube was packed with cupric oxide wire of about 0.1 mm diameter and 5 mm length. Plugs of glass wool at each end held the cupric oxide packing in place. A tube temperature of 1000 F was maintained by control of the electric furnace. The small combustion tube for burning any impurities in the oxygen supply was also of fused quartz, packed with cupric oxide and maintained at 1000 F.

The calcium chloride used was heated in a muffle furnace at 700 F for 48 hrs. Pellets of potassium hydroxide were placed in the tube following the sulphuric acid to pick up most of the CO_2 which might escape absorption in the aspirator bottle. A pressure of only 10 mm Hg was sufficient to pass gas through the apparatus at 200 cc per minute with fresh reagents but when the absorption reagents were ready for replacement this pressure had increased to 50–60 mm Hg.

Testing Procedure for Average Traverse

The testing procedure was as follows: When the desired rating and fire bed were obtained on the boiler, CO_2 readings were taken to check the excess air and the furnace draft and windbox pressure were noted. The aspirator bottles were filled with acidulated water and hose connections made to the sampling tubes. With the tubes in position, the water was allowed to drain from the aspirator bottles and regulated so that each point in the traverse was sampled for three minutes. Orsat readings were taken to determine the CO_2 at each point. Boiler outlet and economizer outlet samples were taken simultaneously. The samples were brought to the laboratory for analysis.

Laboratory Analysis of Combustibles

In the laboratory an Orsat analysis was made to determine the average CO_2 and O_2 in the gas sample. The temperature and pressure in the large aspirator bottle were recorded and 200 ml of 30 per cent potassium hydroxide was introduced to remove the CO_2. The bottle was gently agitated until no further change was noted in the manometer readings, showing nearly complete absorption of CO_2. The draining hose was then connected to the cold water tap and water admitted until the gas pressure was atmospheric. The weights of the Midvale absorption bottles were recorded and the gas displaced through the train at a speed of about 200 ml per minute by adjusting the flow of water into the bottle.

At this point CO_2, SO_2 and SO_3 have been removed by the potassium hydroxide solution in the bottle and the water vapor pressure has been reduced considerably. The concentrated sulphuric acid removes the remaining water vapor. The next four absorption tubes containing pellets of potassium hydroxide, calcium chloride and ascarite remove any traces of water vapor or acid gases that would be absorbed after passing the combustion tube.

In passing through the combustion tube, carbon monoxide, hydrogen and hydrocarbons, if present, were burned to CO_2 and H_2O. The water then was absorbed in the calcium chloride and the CO_2 in the ascarite absorption bottle. When all the sample was displaced through the train, oxygen was admitted for about 10 min to sweep through the remaining sample and to reoxidize any cupric oxide that had been reduced in the combustion tube. The absorption bottles were then weighed and the gain in weight recorded. During the course of running fifty samples no CO_2 could be detected in the last ascarite tube before the combustion furnace, establishing the fact that no results were in error due to contamination by CO_2 originally present in the sample. The same held true for the last ascarite tube after the furnace, thus eliminating the possibility of error due to incomplete absorption.

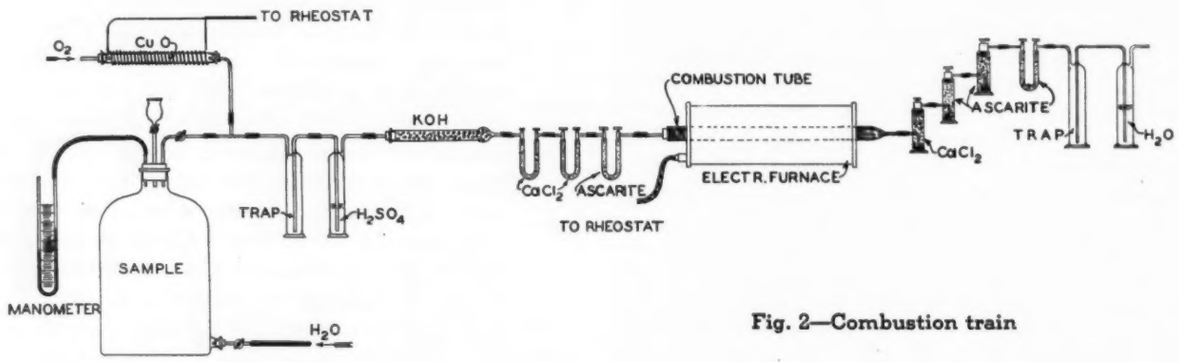

Fig. 2—Combustion train

In order to determine how closely the results could be checked and whether there was any oxidation of CO while the gas remained in the sample bottle, two identical samples were drawn simultaneously from the boiler through one sampling tube and a "T" connection. When brought to the laboratory for analysis, one sample was analyzed two hours later than the other. The percentage error in the CO results was 1.4 per cent while that in the hydrogen was 2.0 per cent. When further tests gave the same results the accuracy of the determinations was judged to be quantitatively excellent. Oxygen was passed through the train continuously, while samples were not being analyzed, but at a rate of only 40–50 ml per min. The average gain in weight per day on each Midvale adsorption bulb varied between 0.5 and 1.0 mg during the 20 hrs the train was not in use.

Relation between Combustibles and Average Carbon Dioxide

It was decided at the outset to attempt to establish a relationship between excess air and incomplete combustion by plotting the per cent of total carbon unburned, which will be called the per cent TCU, against CO_2 concentration. The per cent TCU, arithmetically is

$$\frac{100 \times \% \text{ CO by vol.}}{\% \text{ } CO_2 \text{ by vol.} + \% \text{ CO by vol.}}$$

Ten tests were made on simultaneous traverses of the boiler outlet and the economizer outlet. Two facts were noted from the results. Although a definite trend existed, the per cent TCU varied between wide limits for given CO_2 values and on some tests the sample taken at the economizer outlet showed a higher value for per cent TCU than the sample from the boiler outlet. Since this latter condition was obviously absurd, some fundamental reason was sought and discovered to be in the method of sampling.

For example, let us take the following case. A sample is taken at ten points by traversing the boiler outlet.

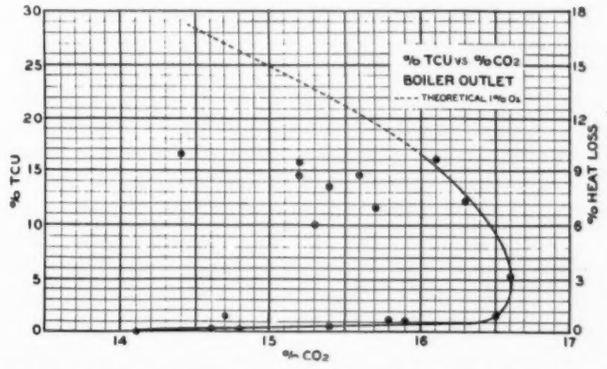

Fig. 3—Per cent TCU versus per cent CO_2 at boiler outlet

The average CO_2 in the sample is 14.3 per cent. For this value CO_2 we expect little or no per cent TCU. But this gas is made up of ten equal parts, from ten sampling points, each of different CO_2 concentrations as follows:

Points Traversed	Per Cent CO_2
1	13.0 no CO
2	13.7 no CO
3	14.3 no CO
4	14.8 CO present
5	15.6 CO present
6	15.8 CO present
7	14.9 CO present
8	14.2 no CO
9	13.6 no CO
10	13.1 no CO
Avg.	14.3 CO present

Points 1, 2, 3, 8, 9, 10 may have no TCU, but points 4, 5, 6, 7 will. If this sample had all been taken from point 3, the curve would show no TCU value for this CO_2 concentration but when the ten points are averaged we find an appreciable amount of TCU. With a more even fire, giving the same average CO_2 but with a lower maximum point, a lower TCU value will be found. These results were substantiated in further tests and will be discussed more fully later.

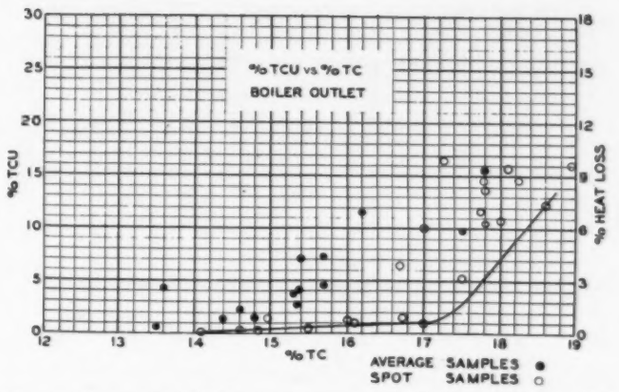

Fig. 4—Per cent TCU versus per cent TC at boiler outlet

Relation between Combustible and Carbon Dioxide in Spot Samples

In view of these facts it became obvious that instead of average samples, spot samples taken as quickly as possible, were needed to determine the per cent CO_2—per cent TCU relationship. Accordingly, a set of tests was made on spot samples in which a 22-l sample was drawn in about 30 sec. As expected, the TCU values decreased for given CO_2 concentrations, and the results in general were more consistent but still not satisfactory.

Discussion of Results

As will be seen from the curve of Fig. 3, the maximum CO_2 obtainable at the boiler outlet was 16.5 per cent. Reducing the air, from this point on, results in CO_2 being reduced to CO, the curve turning back and approaching the theoretical condition of 100 per cent TCU and 0.0 per cent CO_2. The dotted part of the curve is the theoretical curve for one per cent residual oxygen, the oxygen concentration found existing at these conditions in the tests.

In order to eliminate this reverse in the curve, per cent TCU was plotted against $CO_2 + CO$, or total carbon. Figs. 4 and 5 show the difference between spot and average samples from both the boiler outlet and economizer outlet.

An explanation is due at this point as to the reason for drawing a curve through the lowest per cent TCU values. From the previous discussion on spot sampling,

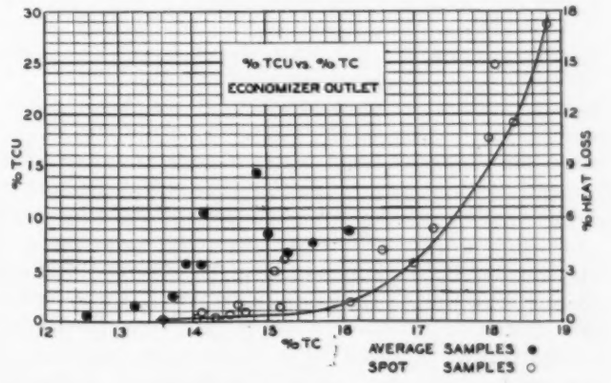

Fig. 5—Per cent TCU versus per cent TC at economizer outlet

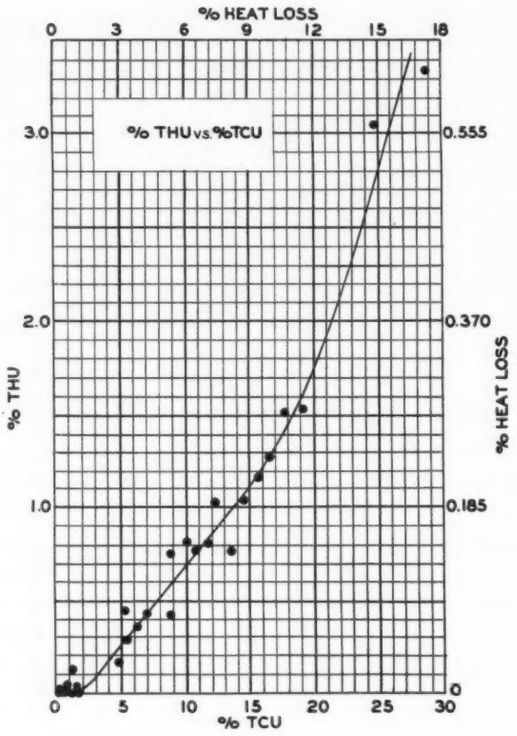

Fig. 6—Per cent THC versus per cent TCU

as compared to average sampling, it can readily be deduced that even in a spot sample the effect of averaging different gas composition is still present to some extent, due to two factors. First, is a change in the fire or excess air during the time the particular sample leaves the fire, and second, an unavoidable mixing of gases of different composition. A curve drawn through the lowest per cent TCU values, therefore, shows a closer approach to the true relationship, because the composition of the gas samples for these points must have remained closer to their original composition after leaving the combustion zone.

Oxidation of Combustible Gases in the Economizer

All tests made on the economizer outlet, both spot and simultaneous average, were made to determine whether appreciable oxidation, of catalytic nature, takes place after the gases cool below their ignition point. The results were inconclusive, although it is known that carbon monoxide does oxidize in the presence of certain metallic oxides at low temperatures. The greatest difficulty is caused by air leakage into the boiler. This leakage cannot be determined from the analysis of a spot sample because its effect is identical to that of excess air. The average leakage, as determined by simultaneous traverses at the boiler outlet and economizer outlet for CO_2, averaged 11 per cent for ten tests. But when the results were plotted on the same scale as Fig. 3, and correction made for 11 per cent leakage, the high per cent TCU values were not in agreement as they should be. With very high TCU values, the oxygen concentration is small and appreciable oxidation is impossible. The best method available to determine oxidation would probably be to apply that correction for air leakage which would make the curve for the economizer samples coincide with the boiler outlet curve at the high per cent TCU values (Figs. 4 and 5).

Unburned Hydrogen

Nothing has been said up to this point of unburned hydrogen or hydrocarbons as a source of heat loss in the flue gas because their presence in appreciable amounts is shown to be unlikely under operating conditions. But since this point has been the subject of much discussion, hydrogen was determined on all tests. No attempt was made to distinguish free hydrogen from that combined with carbon, the value called unburned hydrogen representing hydrogen in any combustible chemical combination.

The relationship between unburned hydrogen and excess air is not shown but the percentage of total hydrogen unburned (THU) is practically a straight line function of the TCU. This relationship is shown in Fig. 6 with a scale showing the percentage heat loss. The carbon monoxide-hydrogen relationship is again plotted in Fig. 7, but on a volume percentage basis, so that the theoretical maximum methane (CH_4) values may be shown.

Heat Losses

It is obvious from these results that the probability of appreciable heat losses from unburned hydrogen or hydrocarbons is very remote. From the heat loss scale on Fig. 6 it may be noted that a value of 8.0 per cent TCU is required for the heat loss from unburned hydrogen to reach 0.1 per cent, a condition seldom existing in normal boiler operation. Houghton[1] gives data on loss in boiler efficiency due to unburned flue gas, showing by means of curves the difference between the Orsat CO loss and the total heat loss due to CO plus hydrocarbons. Since the hydrocarbon loss is small the chief cause of discrepancy between his two curves lies in the large error produced by incomplete absorption of CO

[1] B. Houghton, "The Burning of Bituminous Coal on Large Underfeed Stokers," *Int. Conf. Bit. Coal*, II, 278(1931).

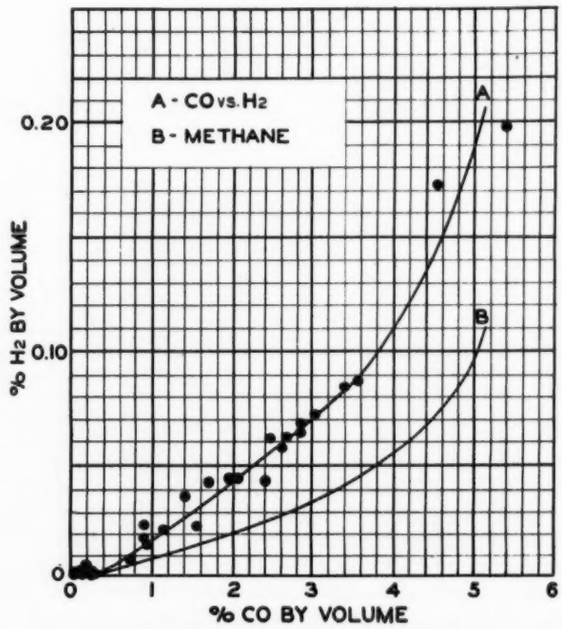

Fig. 7—Carbon monoxide versus hydrogen

by the conventional Orsat apparatus. Since the heat loss value is so small it makes no appreciable difference whether hydrogen be considered combined as a hydrocarbon or free, so this point was not investigated. The heat loss scales, for all curves in this report, are computed from the average ultimate analysis of Heisley, Berwind, Colver and Revloc coals on the "dry" basis.

Discussion of Theory of Combustion

The combustion of coal in a boiler with an underfeed stoker is a complicated process, involving many chemical, physical and mechanical reactions. Most important from the physical standpoint, of course, is the release of all the available heat from the coal in the furnace. This requires complete combustion, a condition which is never attained, due to incomplete combustion of solid carbon in the ash and fly cinder. But the complete combustion of gaseous products is easily attainable if the right conditions prevail. Only the latter point will be considered.

As coal is fed into the stoker the first reaction which occurs in the coal is the evaporation of moisture. As the temperature of the coal rises, the volatile matter is driven off, the coal cokes and the fixed carbon burns as the coke travels down the stoker. There are, therefore, two kinds of fires; one, the combustion of the volatile constituents, and the other, the combustion of coke. Of these two fires, the coke fire is probably the more complicated and will be discussed first.

A clear picture of the reactions occurring in an underfeed coke fire is presented by Nicholls'[2] work. In these tests, coke of 1.5 in. size was burned in a small furnace 20 in. in diameter and 44 in. from grate bars to top, with forced draft. Gas samples and temperature measurements were taken at different levels in the furnace so that the reactions might be shown graphically in relation to the plane of ignition which constantly descends. The results are reproduced in Fig. 9. From this it will be seen that the first reaction of $C + O_2 = CO_2$ reaches its maximum completion 3 in. above the plane of ignition at which point the temperature of the fire surface is about 2400 F. From this point upward the endothermic reaction $CO_2 + C = 2CO$ begins and continues till a point 11 in. from the plane of ignition is reached. Here, an equilibrium is seemingly reached between the $CO_2 + CO + C$ and any further change taking place is very slight.

All the air admitted to the furnace passes up through the incandescent coke and leaves the fire in the composition shown in Fig. 9, being 8.0 per cent CO_2, 22.0 per cent CO and 70.0 per cent nitrogen. If no air is admitted over the top of the fuel bed the CO cannot burn, and 73 per cent of the total carbon in the gas is incompletely burned (73 per cent TCU). An increase in air flow does not serve to complete the combustion, but only increases the rate of these reactions, and the gas composition leaving the furnace will be the same. Therefore in order to run the furnace under conditions of complete combustion, air must be admitted which does not pass through a bed of incandescent carbon.

[2] "Underfeed Combustion," P. Nicholls, *Bureau of Mines Bulletin* 378, p. 50.

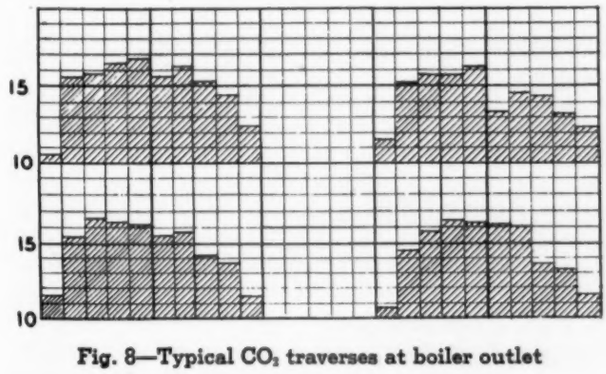

Fig. 8—Typical CO_2 traverses at boiler outlet

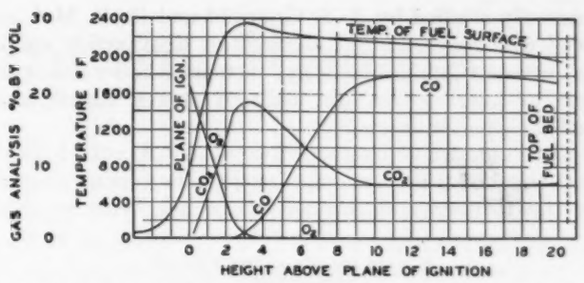
GAS ANALYSIS % BY VOL
TEMPERATURE °F
HEIGHT ABOVE PLANE OF IGNITION
TEMP. OF FUEL SURFACE
PLANE OF IGN.
TOP OF FUEL BED
CO
CO2
O2
0 2 4 6 8 10 12 14 16 18 20
0 400 800 1200 1600 2000 2400
0 10 20 30

Fig. 9—Gas analysis and temperature versus height above plane of ignition

From Nicholls' data on the analysis of the gas leaving the fuel bed the necessary air to burn the CO present can be computed. For each 100 cu ft of air which passes through the fuel bed, 57 cu ft are necessary for complete combustion, and an additional 47 cu ft are necessary to provide 30 per cent excess air (100/204 = 49 per cent). Obviously, in order to secure complete combustion with 30 per cent excess air, about 50 per cent of the total air must react with the incandescent coke and 50 per cent must be admitted as overfire air. This balance of air is obtained fairly well in operation except when the fuel bed becomes noticeably uneven, with heavy spots closing over the tuyères.

In the test run on average samples from a traverse, this effect was noticed several times, the result being high TCU values for given values of CO_2.

In the coals used on these tests, the volatile matter varied between 17 and 22 per cent. When this volatile matter is driven off on the top end of the stoker, about 20 per cent of the total fuel is released in gaseous form in a relatively small portion of the furnace. This, together with the fact that about 20 per cent of the volatile matter is hydrogen, demands that a greater proportion of air be admitted at the front end of the stoker. Since there is no great amount of turbulence, mixing is relatively slow, and the gases might be cooled by the boiler tubes below their ignition point before the required oxygen is met.

The average C/H molecular volume in the coals used in these tests is 3.18. But from Fig. 7 it can be seen the C/H ratio in combustible form in the flue gas is about 40.0. This indicates that under present operation, the combustion of the volatile matter is satisfactory. From the available data it is difficult to determine to what extent carbon monoxide and hydrocarbon losses are influenced by time, proper gas mixing and air distribution. Repeating these tests at different coal burning rates should show the effect of the time element. The results of improved gas mixing can only be guessed at, but it is safe to say that its effect would be desirable. The problem of air distribution, however, has been in-

tensively studied by A. S. Griswold and H. E. McComber,[3] who conclude that metered air distribution results in increased stoker capacity, increased boiler efficiency due to lower excess air, reduced stoker maintenance and a reduction in smoke.

One undesirable characteristic of a stoker-fired boiler, and this boiler in particular, is the slow mixing of gases in the furnace and through the tubes, with resulting

FLUE GAS ANALYSIS - AVERAGE SAMPLES
(SIMULTANEOUS)

BOILER OUTLET				ECONOMIZER OUTLET			
% CO_2	% CO	CO_2+ CO	% TCU	% CO_2	% CO	CO_2+ CO	% TCU
13.4	0.091	13.49	0.67	12.5	0.055	12.56	0.44
15.0	2.75	17.75	15.5	12.7	2.13	14.83	14.4
14.3	0.315	14.62	2.16	13.0	0.203	13.20	1.54
14.6	1.12	15.72	7.12	14.2	1.03	15.23	6.73
14.8	0.567	15.37	3.70	13.4	0.353	13.75	2.57
14.1	1.86	16.26	11.5	12.7	1.51	14.21	10.7
15.8	1.71	17.51	9.76	14.4	1.19	15.59	7.58
15.0	0.692	15.69	4.41	13.0	0.867	13.87	5.83
14.3	1.09	15.39	6.99	13.7	1.30	15.00	8.64
14.7	0.632	15.33	4.10	13.3	0.804	14.10	5.70

FLUE GAS ANALYSIS - SPOT SAMPLES

BOILER OUTLET

% CO_2	% CO	CO_2+ CO	% TCU	% H_2	$\frac{100 \times H_2}{TC}$	% THU
14.6	0.03	14.63	0.20	.0012	.0082	.0261
16.0	1.94	17.94	10.8	.0451	.251	.798
14.7	0.228	14.93	1.53	.0012	.0081	.0258
16.1	3.07	19.17	16.0	.0733	.382	1.216
15.6	2.67	18.27	14.6	.0623	.343	1.09
15.2	2.60	17.80	14.6	.0592	.333	1.06
14.8	0.022	14.82	0.149	--	--	--
14.1	0.008	14.11	0.057	--	--	--
15.7	2.08	17.78	11.7	.0451	.254	.806
15.4	2.40	17.80	13.5	.0433	.243	.772
14.4	2.84	17.24	16.5	.0696	.404	1.285
15.2	2.86	18.06	15.8	.0668	.370	1.18
16.5	0.242	16.74	1.46	--	--	--
15.9	0.166	16.07	1.03	--	--	--
15.4	0.084	15.48	0.539	--	--	--
15.3	1.70	17.00	10.0	.0439	.258	.822
16.3	2.27	18.57	12.2	.0608	.328	1.04
16.6	0.907	17.51	5.21	.0254	.145	.462
15.8	0.204	16.00	1.28	.0074	.046	.146

ECONOMIZER OUTLET

% CO_2	% CO	CO_2+ CO	% TCU	% H_2	$\frac{100 \times H_2}{TC}$	% THU
15.0	0.177	15.18	1.17	--	--	--
15.8	0.263	16.06	1.64	--	--	--
14.8	3.54	18.34	19.1	.0895	.486	1.547
14.8	3.20	18.00	17.8	.0850	.474	1.510
16.0	0.938	16.94	5.54	.0156	.0922	.294
15.7	1.54	17.24	8.93	.0234	.136	.432
13.4	5.41	18.81	28.75	.199	1.06	3.37
13.6	4.50	18.10	24.90	.174	.958	3.05
15.4	1.16	16.56	7.00	.0225	.135	.430
14.7	1.42	16.12	8.95	.0391	.243	.772
14.2	0.914	15.11	6.03	.018	.118	.375
14.4	0.746	15.15	4.92	.008	.053	.169
14.0	0.026	14.03	0.185	--	--	--
13.6	0.024	13.62	0.176	.0012	.0088	.0282
14.4	0.070	14.47	0.484	--	--	--
14.0	0.131	14.13	0.926	--	--	--
14.6	0.115	14.72	0.780	.0028	.019	.0604
14.3	0.028	14.33	0.195	.0012	.0084	.0267
14.4	0.237	14.64	1.62	--	--	--

excessive stratification. This fact, together with poor air distribution, accounts for the peculiar CO_2 traverses show in Fig. 8. Differences of 5.5 to 6.0 per cent in CO_2 readings occur between the center and side walls. If the boiler is operated with 30 per cent excess air (determined by a CO_2 traverse at the boiler outlet) the excess air in the center of the boiler will be much less than 30 per cent with CO_2 readings closer to 15.5 per cent than 13.5 per cent. With high CO_2 readings through the middle of the boiler CO can be expected (Fig. 3) and with it an appreciable heat loss.

In looking at the data, under average samples at the boiler outlet, it will be seen that all the tests showed the presence of CO. More tests should have been run at average CO_2 values in the range of 13.0 to 14.5 per cent; but from the spot samples a per cent CO or per cent TCU value can be assigned to each CO_2 point in the traverse and an approximation of the average per cent CO or per cent TCU made.

A more even air distribution in the furnace would reduce the heat losses occurring under the present conditions, and permit a lower excess air, which might be advantageous. Clinkers, and holes in the fire, were conditions seldom encountered during these tests because the fire was generally cleaned before testing. However, in the four tests run with poor fires, the CO was always much higher than with good fires. The effect of clinkers or holes is evidently that of poor air distribution.

APPENDIX

CALCULATIONS

$$\% \text{ CO by volume} = \frac{\text{gm } CO_2 \times T \times 760 \times 22.4 \times 100}{V \times P \times 273 \times 44}$$

gm CO_2 = grams of CO_2 weighed
T = existing temperature
V = volume occupied
P = pressure, mm Hg
760 = standard pressure
273 = standard temperature
22.4 = gram molecular volume
44 = molecular weight CO_2

$$\% \text{ THU} = \frac{\% \text{ CO by volume} \times 100}{\% \text{ CO by vol.} + \% \ CO_2 \text{ by vol.}}$$

$$\% \ H_2 \text{ by volume} = \frac{\text{gr } H_2O \times T \times 760 \times 22.4 \times 100}{V \times P \times 273 \times 18}$$

gr H_2O = grams of water weighed
18 = molecular weight H_2O

$$\% \text{THU} = \frac{100 \times \% \text{ H by volume}}{(CO_2 + CO) \times 0.313}$$

0.313 = molecular ratio of hydrogen to carbon in avg. coal analyses.

$$\frac{\frac{\% \text{H by wt in coal}}{2}}{\frac{\% \text{ C by wt in coal}}{12}} = \frac{12 \text{ H}}{2 \text{ C}} = \frac{6 \text{ H}}{\text{C}} = 0.313$$

H = 4.36
C = 83.16

Heat Loss Due to TCU: Based on Avg. of Ultimate Analyses of Berwind, Revloc, Heisley & Colver coals.

$$\% \text{ HL for } 10.0\% \text{ TCU} = \frac{0.10 \times 83.16 \times 14{,}600 \times (94{,}385 - 26{,}428)}{14{,}590 \times 94{,}385} = 6.00\%$$

Carbon	83.16%	0.10 = TCU
Hydrogen	4.36	83.16 = % C in coal
Oxygen	3.52	14,600 = Btu/lb for C
Nitrogen	1.32	14,590 = Btu/lb for coal
Sulphur	1.18	26,428 = Heat of formation CO
Ash	6.46	94,385 = Heat of formation CO_2
	100.00	
Btu/lb	14,590	

Heat Loss due to % THU:
(Same coal analysis as above.)

$$\% \text{ Heat Loss for } 1.0\% \text{ THU} = \frac{0.01 \times 4.36 \times 62{,}000}{14{,}590} = 0.185\%$$

0.01 = THU
4.36 = % hydrogen in coal
62,000 = Btu/lb hydrogen
14,590 = Btu/lb coal

[3] Contribution of Fuels Division to A. S. M. E., New York, Dec. 1935.

Power Development in Russia

The contribution of the Russian delegation to the recent World Power Conference, instead of individual papers, was a 500-page book giving a comprehensive review of the fuel situation, power developments and electrification systems as definitely planned and now being carried out in that country. With decentralization of the fuel industry the use of local fuels is being promoted and the experience in burning the various low-grade fuels is related in detail. All power equipment for new stations is now being built in Russia and both boiler and turbine units are being standardized. The progress in station capacity, the employment of large units and high pressures to date far exceeds the prevailing distant conception of what has been going on, as will be apparent from the accompanying brief review.

AT the beginning of 1936 the aggregate installed capacity of Russian power stations was 6,880,000 kw, or 6.3 times that of the pre-war level and 3 times that at the beginning of 1929. Even more rapid has been the electrical output which rose to a total of nearly 26 billion kilowatt-hours in 1935, which was 13 times that of the pre-war level and 5.2 times that of 1928.

In 1928 there was not a single station having a capacity of 100,000 kw or more, the first one of this size being the Shatura, placed in service in 1930. However, by 1935 there were seventeen stations of such capacity or greater, among them seven of more than 150,000 kw each.

There are six principal power systems supplying Soviet Russia, namely, the Moscow, Leningrad, Donetz Basin, Dnieper, Urals and Gorki-Ivanovo. These employ high-voltage networks ranging from 22,000 to 220,000 volts.

The Moscow System is supplied by four stations, namely, the Kashire of 186,000 kw, the Shatura of 180,000 kw, the First Moscow of 120,000 kw and the Stalinogorsk of 100,000 kw. The three stations operating on the Leningrad System are the Red October of 111,000 kw, the Dubrovka of 100,000 kw and the Lower Svir of 100,000 kw. Two stations, the Shterovka of 152,000 kw and the Zuyerka of 200,000 kw feed the Donetz Basin System. The Dnieper System is supplied by the 372,000-kw Dnieper hydro plant. The Urals System has two stations, the Chelyabinsk of 126,000 kw and the Berezniski of 105,000 kw. The Gorki Station of 204,000 kw feeds the Gorki-Ivanovo System, and the Baku region is supplied by the Red Star Station of 109,000 kw.

Incidentally, the Kashira Station has five boilers each of 423,000 lb per hr capacity which rank among the largest in Europe.

The largest turbine units now in operation in any of these stations are 50,000 kw and the ratio of boilers to turbine units is two to one, or less in the later stations. The trend is toward higher steam pressures and temperatures, 850 lb being common and one station in Moscow having three large units operating at 1850-lb gage. Furthermore, many of the later stations are laid out to supply both power and steam for process and heating.

Fuel Supply Decentralized

While Russia has abundant resources of coal, oil and peat, widely distributed throughout the country, the mining industry in old Russia centered within the Donetz Basin where the better grades of coal abounded. In fact, 89 per cent of the total coal output in 1913 came from this region and 92 per cent of the oil from the Caucasian district. However, as these regions were remote from the major industrial centers, long rail haul was necessary and the average mileage far exceeded that of all other classes of freight; in other words, fuel shipments represented over 33 per cent of all freight handled.

Under the present plan of decentralized fuel supply, the aim is to utilize local coals to the fullest extent possible. While many of these coals are of inferior grade, it is claimed that the slightly lessened efficiency and the necessary measures adopted for their burning are more than offset by the decreased freight, and, furthermore, that industrialization of heretofore economically backward areas is promoted. Under this plan the 1935 output exceeded that of 1932 by 42.7 per cent.

The development of local fuel deposits, which in many cases consist of low-grade, high-ash coal, was feasible only through the construction of large regional power stations designed especially to burn the local fuels, and much experimentation was at first necessary.

Much difficulty was encountered in developing methods of successfully firing these fuels owing to their high moisture, ash and sulphur content, and to the low fusing temperature of the ash. Pulverization was found most applicable in the majority of cases, but this required the selection of the proper system of pulverizing, the development of drying methods, the design of new types of furnaces, special means for handling the large quantities of ash and removal of the sulphur from the stack gases.

Utilization of Peat

Of all the local low-grade fuels, peat occupies a special position in the power economy of Russia. The aggregate capacity of peat-fired regional stations at present is 868,000 kw with an output of over four billion kilowatt-hours in 1935. This peat has a moisture content of 25 to 40 per cent, as fired, contains 4 to 15 per cent ash and has a heating value ranging from 2790 to 6660 Btu per lb. Deformation of the ash begins at 1895 F and fusion at 2100 F.

Lump peat is fired on chain-grate stokers and fed through a vertical shaft through which preheated air is

forced for preliminary drying. Water-cooled walls are widely used and boiler efficiencies up to 88 per cent[1] are said to have been obtained.

However, during the past five years the production of milled peat has been steadily increasing, it being cheaper to extract peat by the milling process than by any other method. At first, milled peat was fired along with lump peat by employing special feeders, the milled peat being fired directly into the furnace above the lump peat on the stoker, but it was found that incomplete combustion and high stack losses resulted. Therefore, the milled peat is now being burned in suspension with very satisfactory results. With an initial moisture content of 40 to 55 per cent, evaporation up to 10.14 lb per sq ft of heating surface is being obtained.

Anthracite Culm

This is burned largely in pulverized form and very fine grinding is essential. Several stations were equipped with the storage system and others with the unit system, but experience favors the former, as it insures higher milling efficiency, greater flexibility, less wear on the pulverizing parts and exhausters and easier regulation. The anthracite culm, which ranges from 2.5 to 6.5 per cent volatile, is burned in completely water-cooled furnaces with the water-wall tubes covered with refractory in the region where the coal stream enters the furnace. The turbulent type of burner has given the best results and the temperature of the preheated air must be high, in the neighborhood of 750 F. The fineness has now been standardized as 99 per cent through a 75-mesh screen and 90 per cent through a 180-mesh screen.

Moscow Coal

Moscow brown coal, which runs 30 to 35 per cent moisture, 20 to 38 per cent ash, 3.2 to 6.6 sulphur, and has a heating value of 4340 to 5364 Btu per lb, contains a large amount of pyrites which makes it harder to pulverize and lowers the fusion temperature of the ash. This coal is therefore first prepared by separating out the pyrites, after which it pulverizes easily; but the high moisture content necessitates preliminary drying ahead of the mill. The drying is effected with the coal in suspension in drier pipes, the coal entering the drier being conveyed by an exhauster directly to a cyclone chamber from which it is fed to the mill. The temperature of the drying air varies from 930 to 1020 F and the velocity of the mixture is as high as 115 ft per sec. This operation reduces the moisture to about 22 per cent which is satisfactory for pulverizing, although mill drying is further employed. The system requires about 25 kw-hr per ton of raw coal and the most suitable type of mill is the slow-speed ball type.

When the second section of the Kashira Station was built to burn Moscow coal the 423,000 lb per hr boilers had water walls covered with cast-iron blocks. At heavy loads intense slagging occurred and this necessitated additional water-screening of the upper part of the furnace and the passing of cooling air through all unscreened firebrick areas. As a result of this experience, it has now become standard in later stations to equip the furnaces with plain water walls and water-cooled ashpits; also, to employ corner firing with tangential burners and to limit the temperature of the gases entering the first pass of the boiler to approximately 2000 F.

[1] Although the report does not state, it is likely that this refers to gross rather than net efficiency.—EDITOR.

Steam Power Equipment and Its Manufacture

The Soviet power stations built during the first Five-Year Plan were largely equipped with imported boilers, auxiliaries and turbine-generators. At the present time, however, all the later stations are supplied with equipment manufactured in Soviet plants and designed to meet the prevailing conditions. During the present year steam boilers with an aggregate heating surface of 3,230,000 sq ft will have been built, and the boiler industry began the manufacture of standardized boilers for medium pressure, namely, 483-lb gage and of the following sizes:

Pulverized coal	353,000 lb—single-drum, sectional type
	265,000 lb—double-drum, vertical type
	132,000 lb—double-drum, vertical type
	88,000 lb—single-drum, vertical type
Oil-fired	353,000 lb—single-drum, vertical type
Stoker-fired	88,000 lb—double-drum, vertical type
	44,000 lb—double-drum, vertical type

Designs have been completed for new types of boilers which are to be placed in production in 1937 and which include a 353,000 lb per hr single-drum vertical boiler for pulverized coal to take the place of sectional-header boilers; a 530,000 lb per hr boiler; a 265,000 lb per hr boiler for burning milled peat; and stoker-fired boilers of 265,000 lb and 132,000 lb per hr—all for steam pressures of 498 lb per sq in. The standardized pulverizing unit is the low-speed ball mill built in capacities of 8, 12 and 16 tons. These ratings are based on the use of anthracite culm and when used for Moscow coal the capacities are 50 per cent greater.

Soviet engineers are now faced with the task of introducing higher pressures and temperatures. In 1934 a 60,000-kw installation for power and heating was placed in service at the Union Heat Engineering Institute. This is equipped with two Loeffler boilers, each rated a 331,000 lb per hr maximum at an operating pressure of 1850 lb, and a third boiler of the straight-flow type, of Soviet manufacture, rated at 441,000 lb maximum, 1850-lb pressure and 932 F steam temperature. Similar boilers of 551,000 lb per hr capacity are to be installed in the automobile plant at Gorki and in the new Chelyabinsk heating and power plant.

As in the case of boilers, the Soviet turbine manufacturing plants are now standardizing on turbine types and sizes. Up to now the condensing steam turbines produced in series were rated at 25,000 kw and 3000 rpm, and 50,000 kw and 1500 rpm. However, owing to the widespread development of stations for both power and heating service, new standards have been set up. During the present year 25,000-kw bleeder turbines are being built in series production with steam extraction at 17 lb abs for heating and at 100 lb abs for process uses. A series of 50,000-kw, 1500-rpm condensing turbines is

(*Continued on page 44*)

COAL HANDLING IMPROVEMENTS

at the Miller's Ford Station, Dayton, O.

By R. D. GILLESPIE, Chief Engineer
Dayton Power and Light Company

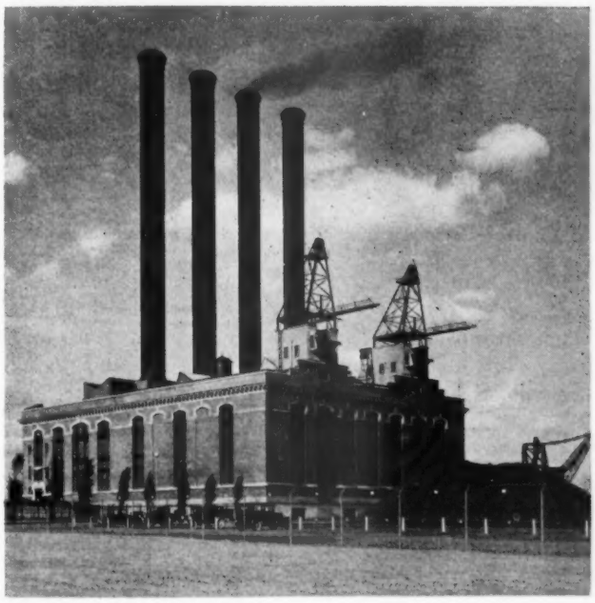

Fig. 1—Miller's Ford Station as it appeared before alterations were started. The near steeple tower and grab bucket is replaced with a fully automatic skip hoist

The new high-pressure extension now being made to this station necessitated considerable rearrangement of the plant layout which involves the replacement of one of the existing coal towers with a modern fully automatic skip hoist system of increased capacity. The new system also will eliminate the dust nuisance which prevailed with the old system of hoisting coal with grab buckets.

MANY owners of central stations, originally designed for extensions to house additional small boilers and additional turbines, to meet future requirements, are confronted by entirely new problems of arrangement, with extensions now taking the form of superimposed turbine-generators supplied by large high-pressure boiler units. Since the new steam generators have larger capacity and are, physically, considerably higher than the old units, it usually follows that existing coal-handling systems are inadequate or are not in the proper locations.

With improvements at the Miller's Ford Station of the Dayton Power and Light Company at Dayton, Ohio, the problem of coal handling was complicated by the necessity of keeping the station in operation while certain of the old boilers were being removed and the new units were being installed.

This station, as indicated on the plan sketch shown herewith, had four rows of boilers placed in pairs with two firing aisles, and above each aisle was a long overhead bunker serving two rows of boilers. One row of boilers has now been removed and the space vacated is to accommodate two high-pressure superposed turbines. Adjacent to this an extension to the building will house the two new 1350-lb pressure, pulverized-coal-fired steam-generating units, each having a maximum capacity of 375,000 lb of steam per hour. These will be supplied with coal by an overhead bunker.

With the augmented steam-generating capacity the old coal-handling equipment would have been inadequate, and it is now being partly replaced. So as not to interrupt operation of the station and to eliminate as much confusion as possible, it was arranged that the new coal-handling equipment should be installed and completed before the new generating additions were put on the line.

The old coal-handling installation consisted of two manually-operated grab-bucket towers located at the south end of each of the two overhead coal bunkers. Coal was deposited in pits under the towers and hoisted about 150 ft by the grab buckets into the receiving

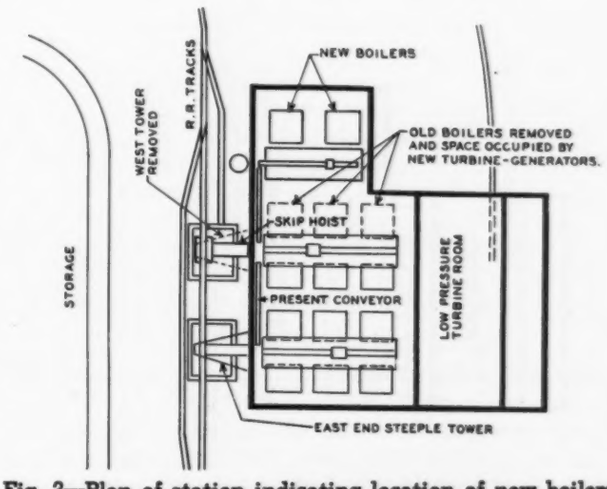

Fig. 2—Plan of station indicating location of new boilers, turbines and coal-handling equipment

hoppers above the roof of the boiler house. It was then chuted either to or around a crusher to a manually-controlled cable-car for distribution over the two bunkers. At the top of the building and under the crushers there was a reversible belt conveyor interconnecting the two systems.

With retention of the old system, the addition of the new, or third, bunker, over the firing aisle of the new boilers, would have necessitated the operation of both coal-hoisting towers at the same time, and would have resulted in a complicated system of coal handling, entailing an abnormally high operating cost.

The old system of hoisting coal with grab buckets created a dust nuisance due to coal leaking from the ascending buckets, which was carried by the wind for a considerable distance. Portions of this dust entered any open windows of the boiler room, while the remainder was carried to the switch yard. Moreover, occasional lumps that dropped from the buckets created a hazard and necessitated the wearing of steel helmets by the coal-unloading crew.

With the new arrangement in the power plant, the new high-pressure turbine room is adjacent to the unloading tracks, so that the elimination of the dust nuisance is imperative.

It was decided, therefore, to install a new fully automatic system, by replacing one of the coal towers with a modern high-capacity automatic skip hoist that normally will handle all the coal for the station. One of the old coal towers is being retained for use in case of emergency.

Operation of New Coal-Handling Machinery

Normally slack coal only is delivered to the plant, and is either dumped directly into the track hopper or stored in the yard by a crane and grab bucket, and rehandled by the same crane to the track hopper.

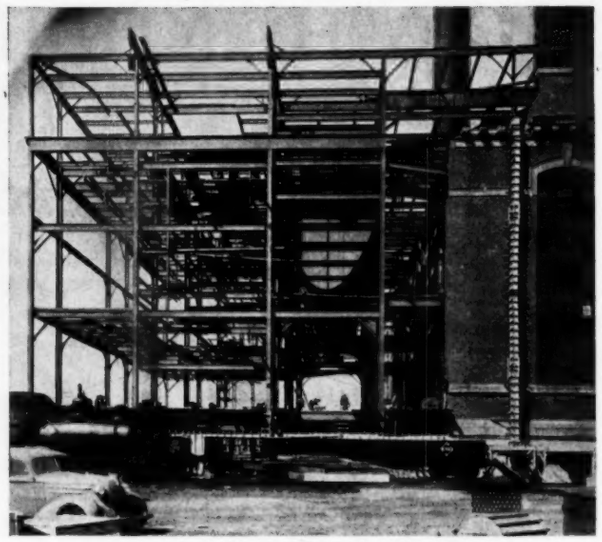

Fig. 4—Construction view of new boiler room

The top of the track hopper is covered with a steel grillage having 12 × 12-in. openings to prevent large foreign objects from entering the system, and to act as a personal safeguard.

The new track hopper is installed under the railroad track in the old grab-bucket pit (see elevation), and the bottom of the hopper is fitted with a gate that automatically fills a skip bucket. The skip hoist elevates the coal about 150 ft and discharges it into a receiving hopper above the roof. The bottom of this receiving hopper discharges the coal onto a slow-moving apron conveyor that discharges onto a vibrating screen. Normally, all the coal passes through the screen and through a three-way chute to the three overhead bunkers as follows:

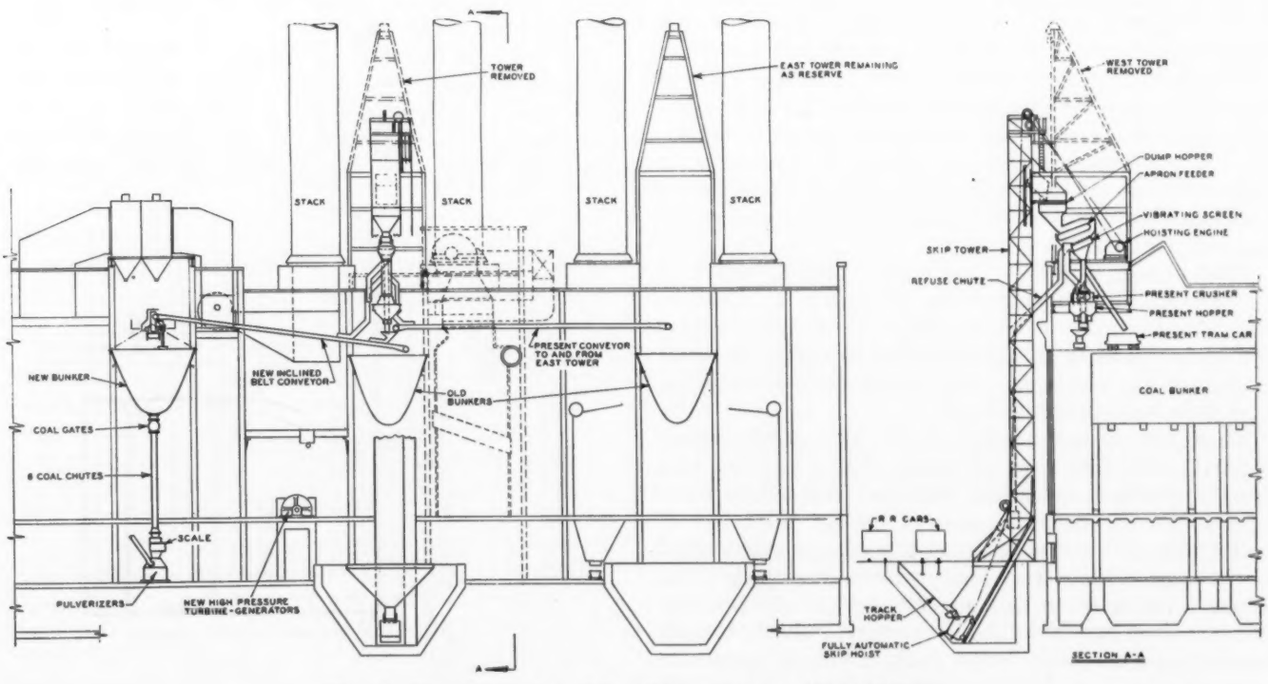

Fig. 3—Elevation of coal-handling system. Dotted lines indicate one of the old towers that has been removed

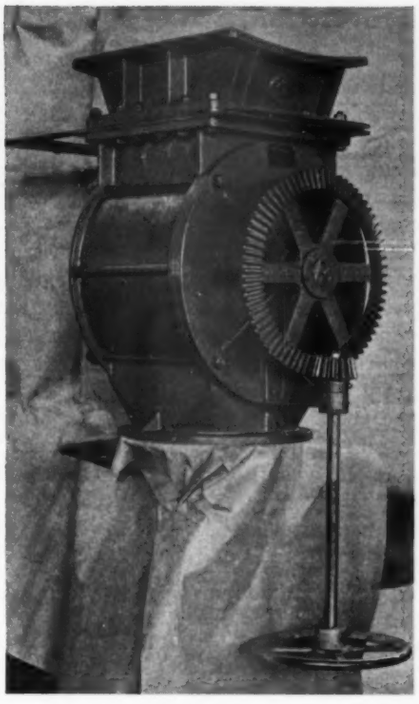

Fig. 5—Shop view of rotary coal gate, six of which are installed in coal spouts from new overhead bunker to mills

West (new) bunker, via an inclined cross belt equipped with a magnetic separator onto a horizontal belt over the new bunker and distributed through a belt-conveyor tripper.

Center (old) bunker, via a chute and the old manually operated cable car.

East (old) bunker, via the old reversible belt and tram car.

A bypass is located under the screen so that lump coal can be crushed if desired. The capacity of the system is 170 tons of coal per hour.

To take care of a light Sunday load the track hopper has been made quite large, having a level-full capacity of 90 tons, and an additional 50 or more tons of coal can be surcharged over it by means of the locomotive crane and grab bucket. By storing this amount of coal in and on the track hopper it is not necessary to have a yard crew on Sunday, for by simply starting the skip hoist this coal can be elevated and discharged into the bunkers automatically.

Fig. 6—Automatic skip bucket of 175 cu ft capacity

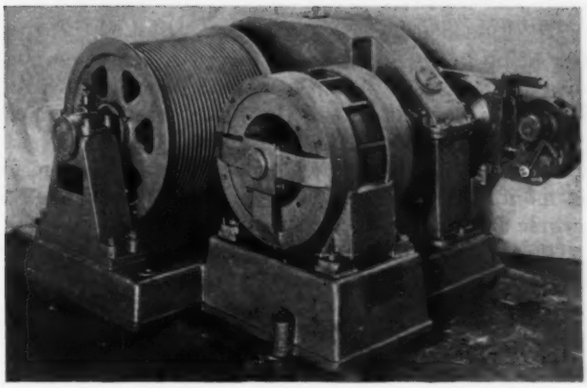

Fig. 7—Skip hoist engine assembled on shop erecting floor before shipment

This system is electrically interlocked and started from a central switchboard. If any unit of the system should stop, all the units ahead of it will be automatically stopped. When starting, the proper sequence only can be followed. Emergency stop buttons are placed at convenient and strategic locations.

Only one operator is required, and he has simply to start and stop the system, throw the fly gates as required and see that the bins are properly filled before starting-up.

As a rule, slack coal only is received and the object of the vibrating screen is merely to remove large foreign objects and oversize coal. The oversize from the screen is discharged down a chute to the track hopper at ground level. A grillage is placed at the outlet of this chute to retain large foreign material and to pass the coal that is broken as it drops down the long chute.

The new coal-handling equipment together with the new bunker and coal spouts are being furnished and installed by The C. O. Bartlett & Snow Company of Cleveland.

BOILERMAKER'S MUSIC

This is the song of the boiler plant,
A wild, delirious, roaring chant;
The whirr of grinding emery wheel,
The clang of sledge on drums of steel,
The rat-tat-tat of riveting gun,
The whining crane on its noisy run.
The stroke of the blacksmith beating time
Controls the anvil's ringing chime;
While the welding torch with blinding fire
Illumines the mad and boisterous choir.

—William A. Gearon

The above is from the pen of William A. Gearon, gateman at the Heine Boiler Company's plant in St. Louis and is reproduced from the August 20, 1936 issue of the St. Louis Daily Globe-Democrat—*Editor.*

(*Continued from page 40*)

now being finished and a new design is being completed for a 50,000-kw, 3000-rpm machine. The Stalin turbine plant is turning out a 25,000-kw high-pressure turbine for an initial pressure of 1705-lb gage and 498-lb gage back pressure. This plant will also turn out during the first six months of 1937 a 100,000-kw, 3000-rpm condensing turbine and 50,000-kw bleeder turbines.

The engineering policy has fixed the following standard turbine types for manufacture in Soviet plants:

FOR POWER AND HEATING

Kilowatt rating	Bleeder outlet pressure, lb per sq in. abs
50,000	17
50,000	100
25,000	17
25,000	100
12,000	17
4,000	17
2,500	17

FOR CONDENSING SERVICE

Kilowatt rating	Rpm
100,000	3000 and 1500
50,000	3000 and 1500
25,000	3000 and 1500
12,000	3000 and 1500

Hydro Developments

The present installed capacity of hydroelectric stations is 482,000 kw which includes the huge Dnieper development of 372,000 kw (558,000 kw ultimate). The ratio of the output of hydro to total power in Russia is increasing. In 1932 this ratio was 7.3 per cent with the plan calling for 19.5 per cent by the end of 1937.

Scale Prevention Study

Engineers in power plants are continuously facing the problem of scale prevention in steam boilers. In attempting to prevent the formation of scale it is essential that they have available data from which to select the particular treatment required. The purpose of an investigation described in Bulletin No. 283 of the Engineering Experiment Station of the University of Illinois, "A Study of the Reactions of Various Inorganic and Organic Salts in Preventing Scale in Steam Boilers," by Frederick G. Straub, which has just been issued, was to study methods of chemical treatment which might be used for the prevention of the various types of scale which form in steam boilers.

Since the chemical treatment of boiler water may be readily classified under two distinct headings, inorganic and organic, it was thought advisable to divide this study into two parts. The first part describes the results obtained in scale prevention by the use of various inorganic salts; the second part describes the results obtained by the use of various organic materials such as the so-called tannin extracts.

The tests were run in a bomb apparatus, and in a small laboratory boiler arranged so that the conditions of the tests could be varied as desired. The tests indicated that both inorganic and organic materials could be used successfully to hold the scale-forming materials in solution in the boiler water, and thus prevent the formation of scale.

Until March 1, 1937, copies may be obtained from the Engineering Experiment Station, Urbana, Illinois.

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STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Rotary Economizer

The rotating type of economizer, first brought out about ten years ago by Hans Simmon, has steadily gained favor in Germany, according to *Die Wärme* for August 8, 1936, there now being more than three hundred such units in service. In this type the group of ribbed tubes of small diameter rotate at high speed through the flue gas and, because of the turbulence set up, increased heat transfer is claimed. The weight for a given capacity is said to be much less than that of a stationary economizer. In the later designs V-belt drive and water-cooled roller bearings are provided.

Double Return-Tube Boiler

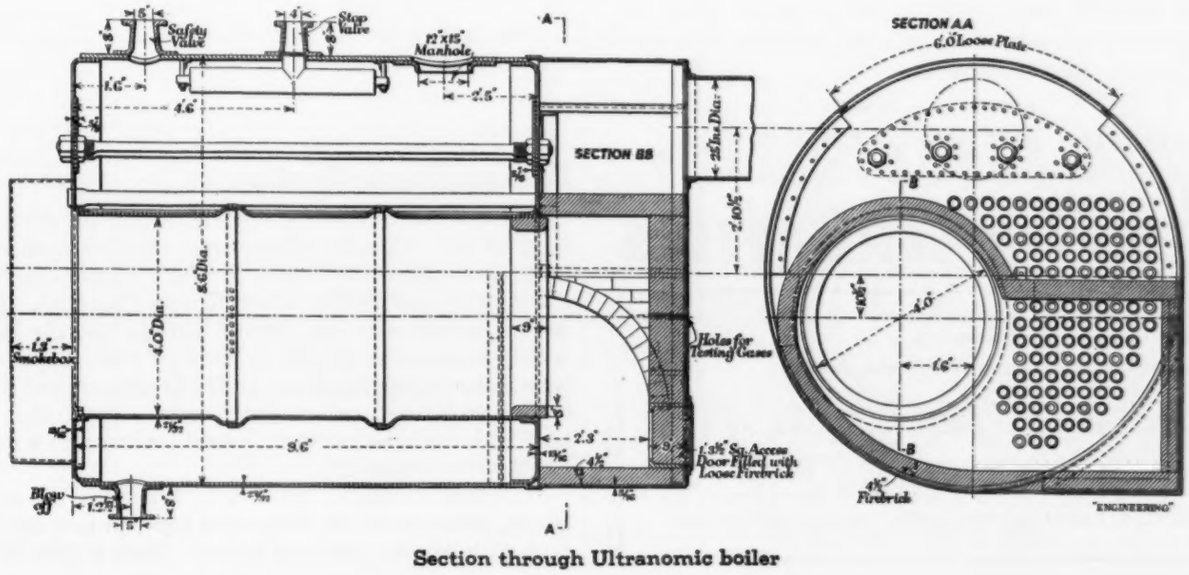
In the Scotch, Lancashire, Cornish and other conventional types of internally-fired return-tube boilers, there is a mass of relatively cold water below the furnace and natural circulation in this section is impeded. To overcome this, Davey, Paxman & Co. of Colchester, Eng., has brought out a design, designated as the "Ultranomic" boiler in which the tube nests are arranged at one side instead of above the furnace. The combustion chamber at the rear is divided by a horizontal partition, so that the lower half receives the gases from the furnace. These pass from the rear to the front of the boiler through the lower bank of tubes and return through the upper bank. Units of this type are being offered for capacities up to 16,030 lb of steam per hr. The illustration is reproduced from a description in the October 23 issue of *Engineering*.

Some British Power Statistics

A recent report of the British Electricity Commission for the period ending March 1935, quoted in the October 22 issue of *The Electrical Times*, shows 7,785,206-kw installed capacity for the utilities. Of this the bulk, 95.84 per cent, is in steam turbine-generator capacity and of the remainder water power accounts for 2.18 per cent. There are at present eight different frequencies in use although 91.9 per cent is 50 cycles. The evaporative capacity of the 2189 boilers installed is 89,215,531 lb per hr and the steam pressures range from 100 to 1100 lb per sq in. About $10^1/_2$ million tons of coal were consumed for the year and the average fuel consumption per kilowatt-hour was 1.57 lb. The connected load was slightly over 20 million kilowatts and the average load factor, covering both municipal and private undertakings, was 33.6 per cent.

Steels for Modern Steam Conditions

L. Sanderson, discussing this subject in the October issue of *Engineering and Boiler House Review*, refers to the use of steel containing 39 per cent nickel and 10 per cent chromium as particularly suitable for the high peripheral speeds of low-pressure turbine blading in order to lessen the rate of erosion and corrosion and at the same time provide the necessary toughness and mechanical strength. In one instance where nickel steel blades lasted only 7600 hr the 39/10 steel blades have been in service nearly six years without being appreciably affected.



Section through Ultranomic boiler

How to increase boiler efficiency & capacity

WOULD YOU like to increase the efficiency of your boiler a minimum of 3%? Would you be interested in raising its capacity another 50-100% of rating?

Such improvements are accomplished by the average installation of Beco-Turner baffles. Unless your baffles have been recently rebuilt in accordance with the principles of modern baffle design, it is probable that new Beco-Turner baffles would make similar improvements in the operation of your boilers.

Beco-Turner baffles put the boiler to work. Beco-Turner design increases the heat-absorbing efficiency of the boiler, while Beco-Turner construction keeps the baffles gas tight throughout their entire life.

It costs you nothing to find out what Beco-Turner baffles will do for you. Our engineering department shall be pleased to submit our recommendations to you for improving the performance of your boilers through more advanced baffle and furnace design. Mail the coupon below and send blueprints showing your settings for our recommendations.

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Firm.....

Address.....

Signed.....Title.....

No. of boilers.....H.P.....Type.....

SEND BLUEPRINTS FOR BAFFLE RECOMMENDATIONS

Current practice in England, according to Mr. Sanderson, tends to confine the heat-resisting steels for steam service to three principal compositions, in addition to the foregoing. The first of these is 19.5 per cent chromium, 7.25 per cent nickel, 4 per cent tungsten, 1.4 per cent silicon and 0.35 per cent carbon. The second, is 26.5 per cent nickel, 11 per cent chromium, 1.5 per cent silicon, 1.5 per cent manganese and 0.3 per cent carbon. This steel is suitable for stokers, pyrometer tubes, conveyors, etc. The third steel contains 22 per cent chromium, 23 per cent nickel, 1.85 per cent silicon and 0.65 per cent carbon. This is especially suitable for high temperature furnace parts, skid rails, grates and rolls.

Another very useful new heat-resisting steel, suitable for valve parts, turbine blading, pump rods and miscellaneous steam applications, contains 20 per cent nickel, 8 per cent chromium, 0.4 per cent carbon and a small amount of silicon and manganese.

Manufacture of Lubricants from Coal and Lignites

The success in the production of synthetic lubricants attained in Germany and England makes it imperative for France to follow their example. Charles Berthelot, in the August 1936 issue of *Chimie and Industrie*, thinks it desirable for the French Government to include such a project in its plan for bringing national means of production up to date. The world's requirement of lubricants is considerable, reaching about six million metric tons per year. In case of international complications it would be necessary for France to manufacture not only synthetic gasoline but also lubricants and it is, fortunately, possible to combine these two processes. The Bergius process permits the manufacture of a satisfactory product from lignites. The Fischer process gives even better results which are able to satisfy the most diversified needs of modern industry and engineering. The author describes the present state of the manufacturing processes for synthetic lubricants which are still in the preliminary stage. He defines the characteristics of a good lubricant and the methods for measuring viscosity and points out that ethylene and paraffine, which are by-products of the Fischer process, represent an important source of great value as a raw material for synthetic lubricants.

Fulham Power Station

The new Fulham Power Station, located on the north bank of the Thames, which was officially opened on September 26, is described in the October issue of *Engineering and Boiler House Review* (London). Laid out for an ultimate capacity of 300,000 kw, the initial section contains six 260,000 lb per hour three-drum bent-tube boilers supplying steam at 625-lb pressure and 850 F to two 60,000-kw turbine-generators. The boilers are fired with multiple-retort underfeed stokers and are provided with economizers.

Superheat control is effected by arranging the superheater, which is of the convection type, in two sections, each with its own inlet and outlet. Each section is fur-

ther divided into a primary and a secondary portion, between which is situated a de-superheater. The steam passes through the primary superheater, then through the de-superheater or, alternately, through a bypass, and thence to the secondary superheater section. The tubes in the primary superheater are of ordinary mild steel, but those of the secondary superheater are of a low carbon steel with a small percentage of copper and molybdenum. The steam temperature is under thermostatic control which regulates the amount of steam passing through the de-superheater.

The turbine-generators are of the two-cylinder type, the high-pressure element having 21 single impulse stages and the low-pressure element 13 impulse stages and double exhaust. Their rotative speed is 1500 rpm. A 10,000-kw Ljungstrom unit is provided for house service.

New German Rules for Welded Steam Boilers

The subcommittee on welding of the German Boiler Committee has submitted to the Reich Minister of Economics for approval proposals for a revision of the existing rules and specifications for the use of welding in boiler manufacture. The new rules, as discussed by K. Vigener in the October issue of *Wärmewirtschaft*, are intended to make possible the application of the present knowledge in this field without handicapping any further developments.

In the future every firm engaging in welding shall be licensed in order to assure good craftsmanship and reliability. Welded vessels shall, as a rule, be normalized although certain exceptions, as noted, can be made. If the wall temperatures of welded drums in service are expected to be equal to or greater than 592 F, data regarding the resistance at high temperature of the materials used shall be submitted (except for boiler-flues, fire-boxes, etc.) Openings cutting through or near welded seams are to be avoided. Allowable stresses for welded seams shall be 0.7 that of the plate.

Applications for exceptions from these requirements, in particular those relating to normalizing, are to be passed on by the German Boiler Committee.

Normalizing is to be carried out at prescribed temperatures depending on the properties of the steel used, it being for some steels as high as 1700 F. The normalizing shall last one minute per 1 mm wall thickness, but in no case less than twenty minutes.

In order to keep down the price of German boilers and to facilitate competition in foreign markets, the rules permit boilers to be exempt from normalizing under certain conditions and the substitution of annealing to relieve welding stresses and, further, in some cases forego heat treatment altogether. Temperatures for such stress-relieving are considerably lower than those required for normalizing, and an improvement of the structure of the weld does not take place. For welds without heat treatment the allowable stresses are not to exceed one-half that normally allowed and only materials easy to weld and sufficiently plastic may be used. This exemption is valid only for boilers with less than 120 lb working steam pressure.

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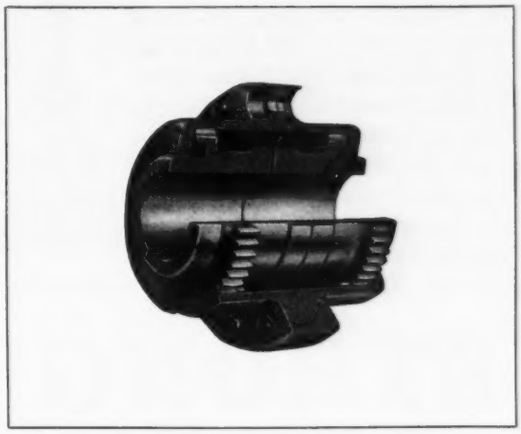

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- High capacity, small size, non-air-binding, and self-scrubbing.
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EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

as reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 164 water-tube and h.r.t. power boilers were placed in September

	Number	Square Feet
September, 1936	164	464,709
September, 1935	101	274,745
January to September (inclusive, 1936)	1,400	4,405,867
Same period, 1935	722	2,434,990

NEW ORDERS, BY KIND, PLACED IN SEPTEMBER 1935–1936

Kind	September 1936		September 1935	
	Number	Square Feet	Number	Square Feet
Stationary:				
Water tube	82	371,790	56	226,270
Horizontal return tubular	82	92,919	45	48,475

Mechanical Stoker Sales

Orders for 499 stokers Class 4* totaling 75,106 hp were reported in September by 46 manufacturers

	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
September, 1936	437	50,690	62	24,416
September, 1935	275	33,148	70	22,112
January to September (inclusive, 1936)	1,793	231,562	472	197,623
Same period, 1935	1,150	150,014	441	164,894

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 12 pulverizers with a total capacity of 82,200 lb per hr were placed in September

STORAGE SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
September, 1936	..	..	..	..	None	None	None
September, 1935	..	..	..	..	...	...	..
January to September (inc. 1936)	..	..	..	..	...	...	...
Same period, 1935	..	..	..	..	...	...	...

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers, Water-tube Boilers			
September, 1936	12	11	1	82,200
September, 1935	7	5	2	102,000
January to September (inc. 1936)	209	155	54	2,116,600 lb coal per hr
Same period, 1935	86	51	35	471,310 lb coal per hr
	Fire-tube Boilers			
September, 1936	...	...	..	.....
September, 1935	...	...	..	.....
January to September (inc. 1936)	19	3	16	22,900
Same period, 1935	4	...	4	4,300

REVIEW OF NEW BOOKS

Any of the books reviewed on these pages may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Handbook of Engineering Fundamentals

By O. W. Eshbach and 40 contributors

In this, the first volume of a new handbook series, is presented a complete summary of facts pertaining to the fundamental theory underlying engineering practice, the basic subjects of mathematics, physics and chemistry being treated. There are also chapters dealing with essential data on various materials of construction.

The first section presents a selection of mathematical and physical tables, engineering constants, logarithms, trigonometric and hyperbolic functions, conversion factors, tables of integrals, standard structural shapes and the physical properties of metallic and non-metallic materials. Other sections cover the theory and application of mechanics; thermodynamics; the latest physical concepts of hydraulics, aerodynamics and heat engineering; the theory of the electric and dielectric circuits; the principles of general chemistry; and the legal aspects of contractural relations, a subject with which all practicing engineers should be familiar.

The size of the book, $5^1/_2 \times 8^3/_8$ in., permits the use of larger type as well as larger illustrations and more workable diagrams than was possible with the older size of handbook.

This is a volume that every engineer, regardless of his specialty, will find most useful. It contains more than a thousand pages and the price is $5, net.

Mechanical Engineers Handbook (Eleventh Edition)

By Robert T. Kent and 28 contributors

It has been thirteen years since the tenth edition of this well-known handbook was published. In the interim there has been much advancement in mechanical engineering, particularly in the power plant field, and time was ripe for a complete revision. Unlike previous editions, the present edition is printed in two volumes, one on "Power" and the other on "Design and Shop Practice"; also the size of the page has been increased to $5^1/_2 \times 8^3/_8$.

There are seventeen sections in the Power Volume covering the entire range of equipment from fuel to switchboard; also hydraulics, thermodynamics, combustion, insulation, refrigeration, heating, ventilating and air conditioning, in addition to much fundamental information, mathematical tables, etc. Power Test Codes are discussed at length as is also the A. S. M. E. Boiler Code.

Most of the chapters give a very excellent cross-section of practice up to the time the material was prepared, which necessarily omits a few of the more recent innovations coming out of 1936 activity in the field. This is unavoidable. The one exception is to be found in the chapter relating to boilers, superheaters, economizers and air heaters where the contributor saw fit to devote the text and all the illustrations to the products of his own company, to the entire exclusion of all other types and designs, many of which are playing an important part in present practice and new construction. From the readers viewpoint this is most unfortunate for the practicing engineer expects a handbook, and especially one of the standing of Kent, to give him full and unbiased information on any subject covered.

The price of this volume is $5.

Practical Boiler Firing

By H. C. Armstrong and C. V. Lewis

A handy little book giving high-spot information for the small plant operator in a most elementary manner. It does not go sufficiently into detail to be of much use to the experienced boiler-room engineer and the text deals entirely with British practice.

There are 132 pages, $5 \times 7^1/_2$ in., cloth bound. Price $1.50.

Mathematical Tables

By Charles D. Hodgman

This is the fifth edition in six years of this handy compilation of mathematical tables and formulas. It includes four- and five-place logarithms, logarithms of trigonometric functions, natural trigonometric functions, hyperbolic functions, tables of areas, circumferences, etc., square and cube roots, factors for computing probable errors, factors and primes, interest tables, algebraic, trigonometric and calculus formulae and many other expressions used in engineering calculations.

In the present edition the material has been more conveniently arranged and explanations of the use of the tables have been added.

The book is nicely and serviceably bound and contains 312 pages, $5^1/_2 \times 8$ in. Price $1.50.

Property Protection

"Industrial Property Protection Throughout the World" is the title of a study prepared by James L. Brown of the Division of Commercial Laws, Department of Commerce. This has been compiled to acquaint the American manufacturer seeking foreign markets with information necessary for the protection of his trade marks, labels and other identifying media. Design piracy is on the increase, according to the Commerce Department, and the chapter devoted to this, as well as to patents for industrial products and processes, will be found most useful.

This handbook comprises 184 pages and may be obtained from the Division of Commercial Laws, Bureau of Foreign and Domestic Commerce, Washington, D. C., or from the Superintendent of Documents, Government Printing Office, Washington, D. C. The price is 20 cents.

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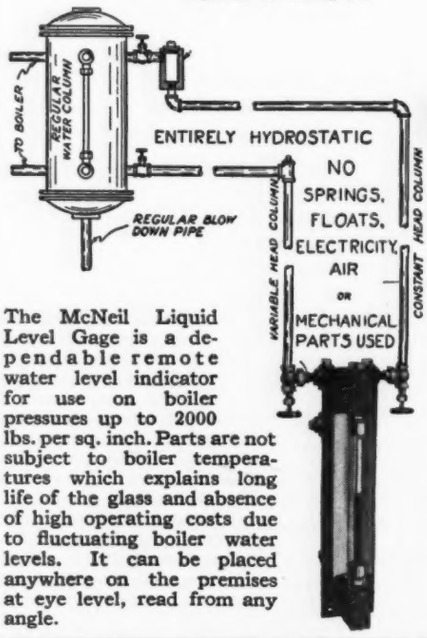

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Rate of Reaction of Sodium Sulphite with Oxygen

Corrosion due to oxygen dissolved in feedwater has long been a serious problem. Efforts to remove the oxygen have been directed along two lines, namely, mechanical deaeration and the employment of chemicals. The former is the most widely used method and the most economical for the removal of the bulk of the oxygen. Under some conditions, however, it is supplemented by chemical deactivation in which sodium sulphite is the agent employed. While not new, it has been used extensively only within the last four years. Since its effectiveness is dependent upon the speed with which it combines with dissolved oxygen an investigation was made to study the effect of temperature, the character of the water and the concentration of sodium sulphite upon the reaction rate. The results of this investigation were reported by R. M. Hitchens and R. W. Towne, of the Analytical Laboratories, Monsanto Chemical Company at the last annual meeting of the American Society for Testing Materials, in Philadelphia.

This investigation showed that the reaction rate is a function of the type of water, its temperature and the excess of the reagent employed. It proceeds roughly five times as rapidly in sea water as in distilled water and ten times as fast in distilled water as in St. Louis city water. It proceeds with great rapidity at 85 C, even in water with strong inhibitory tendencies. In general, a rise of 10 deg C doubles the speed of reaction. A 20 per cent excess of the reagent almost doubles the rate of reaction and a 100 per cent excess of the reagent almost quadruples it.

From the data obtained it seems logical to conclude that the reaction proceeds with great rapidity and that it is complete in less than one minute at temperatures approaching that of boiling water, regardless of the type of water being used if a slight excess of the sodium sulphite is employed.

History of the Ringelmann Smoke Chart[1]

By RUDOLF KUDLICH[2]

Wherever smoke abatement is discussed, the Ringelmann Smoke Chart sooner or later receives attention. It is strange that, though this chart is so commonly used and is of comparatively recent origin, its source and early history have been almost entirely forgotten. Recently an inquiry as to its source, addressed to the secretary of a smoke-abatement organization abroad, after passing through several hands reached the Bureau of Mines.

The Ringelmann Smoke Chart, giving shades of gray by which the density of columns of smoke rising from stacks may be compared, was developed by a Professor Ringelmann of Paris. Professor Maximilien

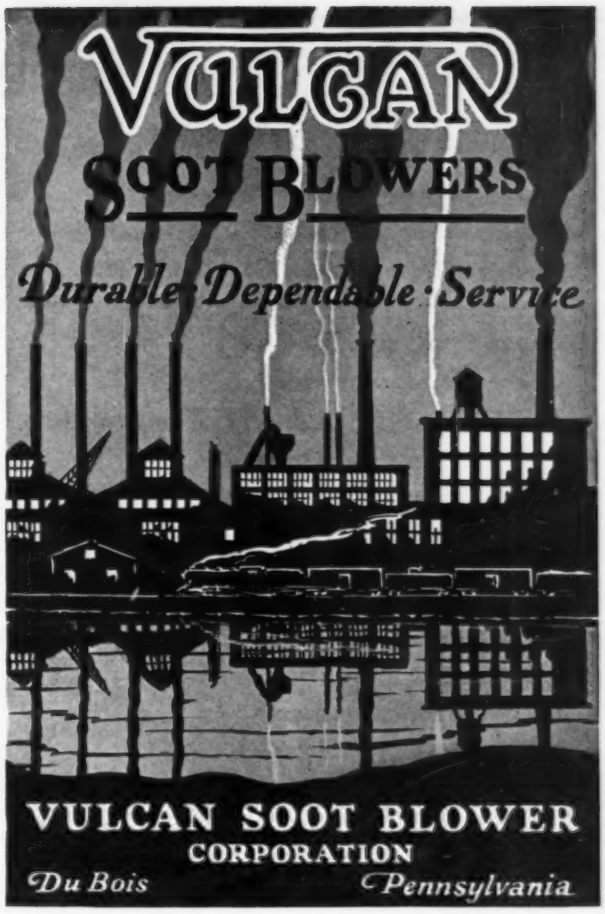
[1] From U. S. Bureau of Mines Information Circular 6888.
[2] Assistant to chief engineer, Mechanical Division, U. S. Bureau of Mines.

Ringelmann was born in 1861, was professor of agricultural engineering at l'Institute National Agronomique and Director de la Station d'Essais de Machines in Paris in 1888, and still held those positions in 1930. He is the author of several textbooks on agricultural engineering.

The chart apparently was introduced into the United States by William Kent in an article published in "Engineering News" of November 11, 1897, with a comment that he had learned of it in a private communication from a Bryan Donkin of London. It was said to have come into somewhat extensive use in Europe by that time. Kent proposed in 1899 that it be accepted as the standard measure of smoke density in the standard code for power-plant testing that was being formulated by the American Society of Mechanical Engineers.

The Ringelmann Chart was used by the engineers of the Technologic Branch of the U. S. Geological Survey (which later formed the nucleus of the present Bureau of Mines) in their studies of smokeless combustion beginning at St. Louis in 1904, and by 1910 had been recognized officially in the smoke ordinance for Boston passed by the Massachusetts Legislature. Since then many city ordinances have accepted it as the standard for measuring smoke density.

In 1908 copies of the chart were prepared by the Technologic Branch of the U. S. Geological Survey for use by its fuel engineers and for public distribution. Upon its organization in 1910, the Bureau of Mines assumed this service together with the other fuel-testing activities of the Technologic Branch.



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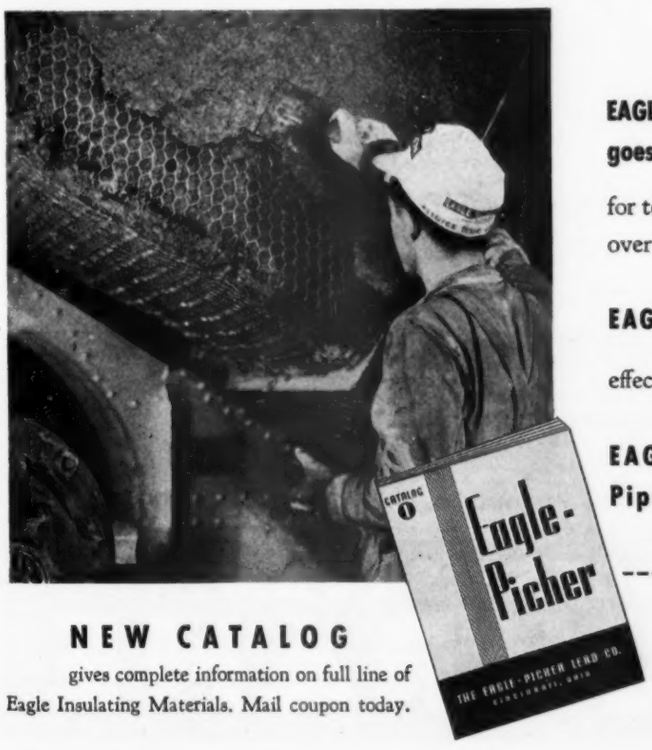

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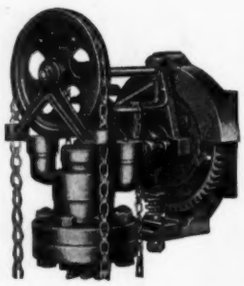

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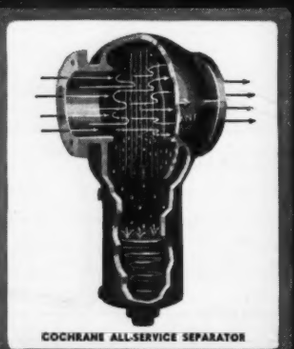

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